Ohio Agricultural Experiment Station.

BULLETIN 110.

WOOSTER, OHIO, DECEMBER, 1899.

THE MAINTENANCE OF FERTILITY.

FIELD EXPERIMENTS WITH FERTILIZERS,

1888 to 1899.

The Bulletins of this Station are sent free to all residents of the State who request them. Persons who wish their address changed should give both old and new address. All correspondence should be addressed to

EXPERIMENT STATION, WOOSTER, OHIO.

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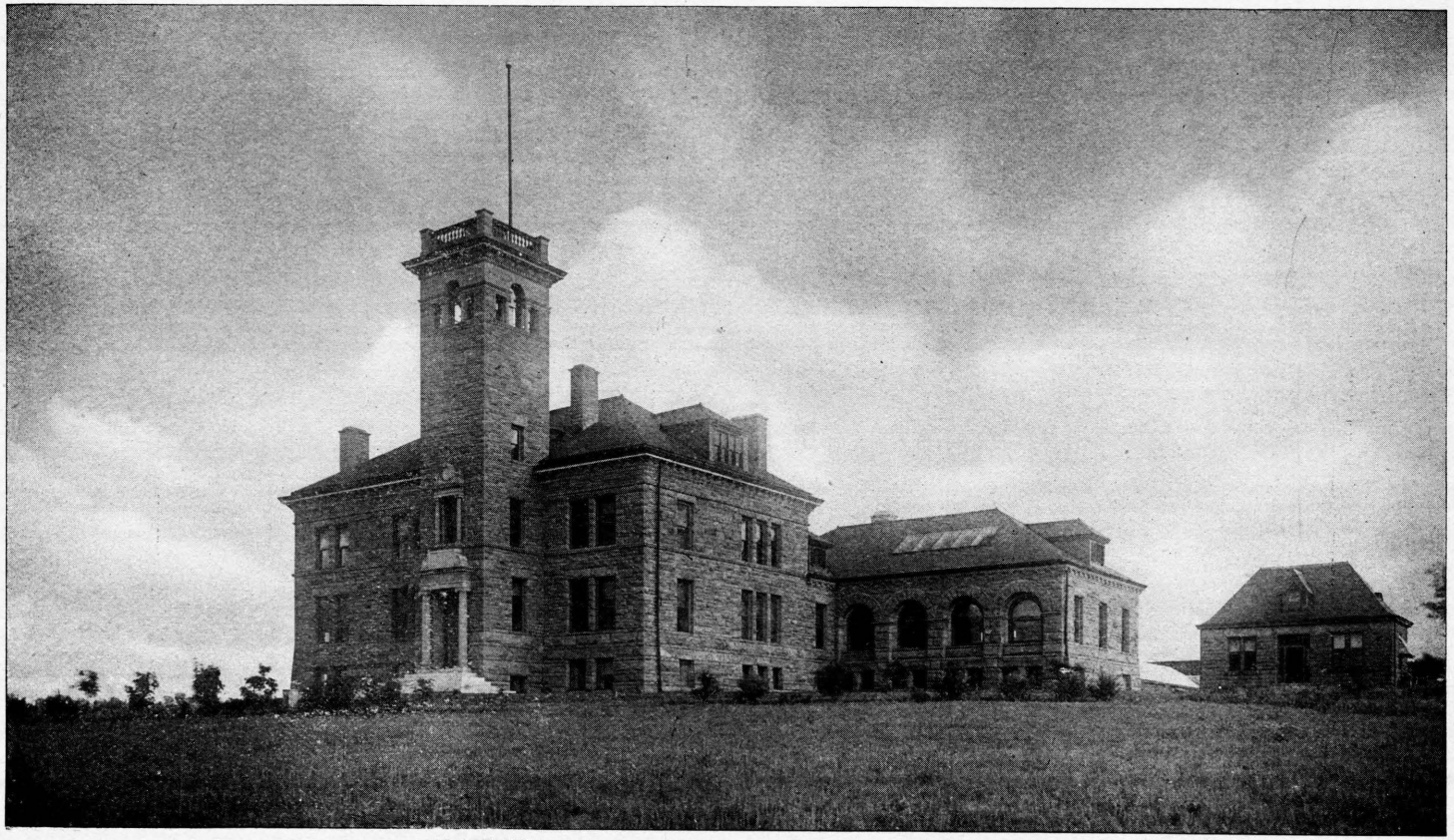
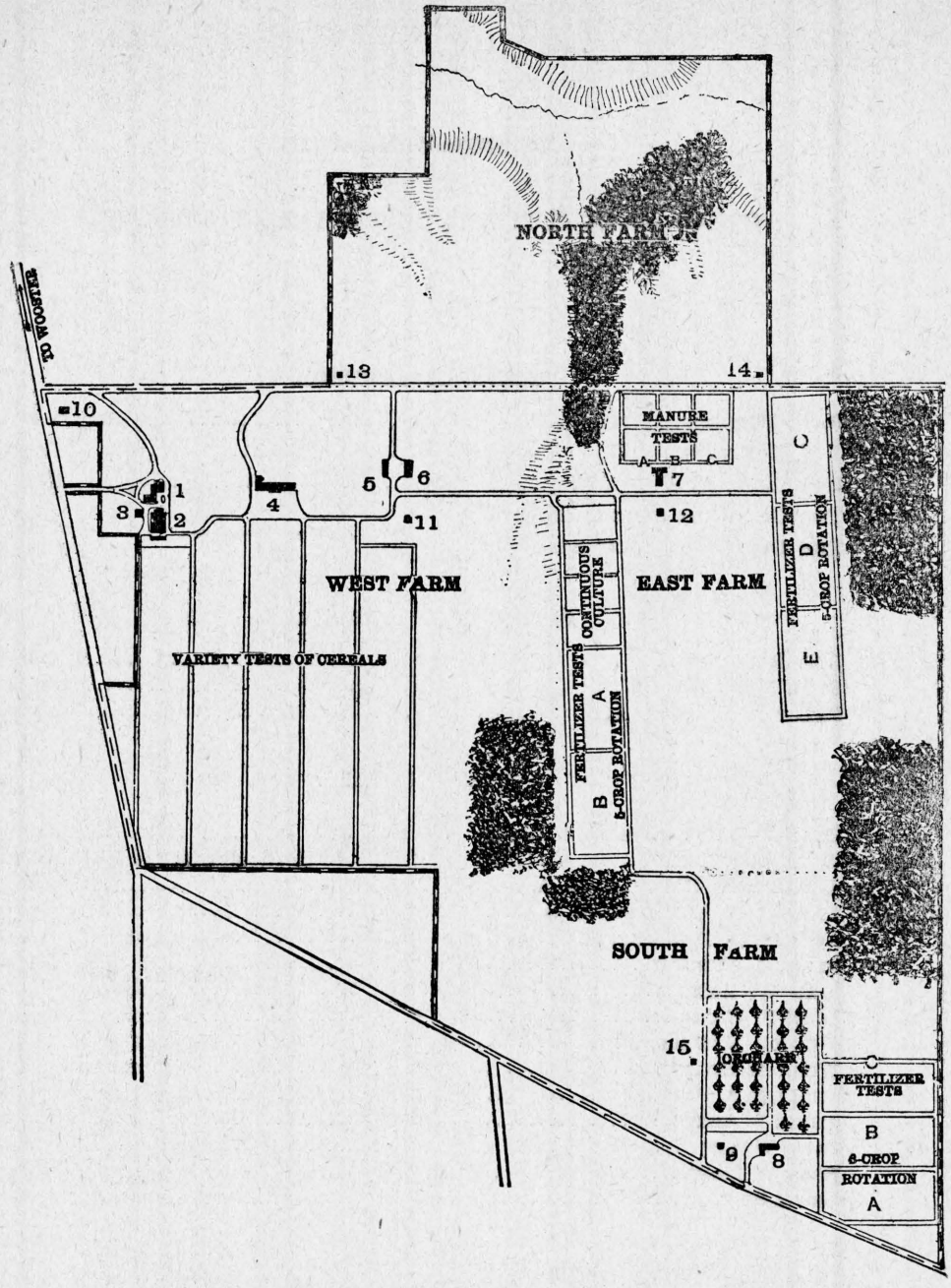


Main Building. Chemical Laboratory. Biological Laboratory.

OHIO AGRICULTURAL EXPERIMENT STATION.



FARM MAP—OHIO AGRICULTURAL EXPERIMENT STATION.

1. Main building.
2. Greenhouses.
3. Biological laboratory.
4. Dairy barn and creamery.
5. Tool house.
6. Horse barn.
7. East barn.
8. Horticultural barn and cold storage.
9. Residence of Horticulturist.
10. Residence of Director.
11, 12, 13, 14, 15. Dwellings occupied by foremen and laborers.

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The Bulletins of this Station are issued at irregular intervals. They are paged consecutively, and an index is included with the Annual Report, which constitutes the final number of each yearly volume.

Bul. 110

BULLETIN

OF THE

Ohio Agricultural Experiment Station.

NUMBER 110. DECEMBER, 1899.

THE MAINTENANCE OF FERTILITY.

BY C. E. THORNE.

INTRODUCTORY.

The investigations reported in the following pages have been conducted, in general outline, upon plans adopted at a conference of experiment station workers, held in Washington, D. C., in March, 1888. For the general oversight of the work and for the discussion of results the Director of the Station is responsible, but it is his very pleasant duty to acknowledge that, in the execution of the work, there has been the most hearty coöperation on the part of all the members of the staff of the Station within whose special departments any portion of it was found.

During the twelve seasons over which these experiments have been continued the Agriculturist of the Station, Prof. J. F. Hickman, has had the immediate supervision of the field experiments upon cereal and hay crops, assisted during the entire period by William Holmes, and for the last nine years by C. A. Patton, Farm Foremen. Prof. W. J. Green, Horticulturist, has conducted the experiments upon potatoes throughout the twelve seasons, and for the last six years Prof. A. D. Selby, Botanist and Chemist, has rendered assistance in the chemical examination of the soils under test and of the fertilizing materials employed. For six years Mr. Edward Mohn has executed the experiments at the Northeastern Substation, at Strongsville, and for two years Mr. Lewis Schultz has performed similar services at the Northwestern Substation, at Neapolis.

Partial reports of this work have been made in the Seventh Annual report of this Station and in Bulletins 17, 27, 29, 39, 49, 53, 71, 80, 93 and 94; but it seems desirable at present to publish a more complete record of the work than has yet been done. If some of the details given should seem superfluous to the reader who cares only for the main results of

the test, it is hoped that they may be found not without value to the scientific investigator.

These investigations have been planned and conducted with a view to obtaining light upon the following points:

1. The relative importance, both to the soils and to the crops under test, of nitrogen, phosphoric acid and potash in the fertilizer.

2. The ratio to each other in which these leading constituents of the fertilizer may be most profitably used.

3. The forms or carriers in which they may be most cheaply and effectively given to the soil.

4. The extent to which the demand for nitrogen in the fertilizer may be satisfied by the culture of clover.

5. The capacities of different species of crop-plants for securing their own supplies of plant food.

6. The proportion of plant-food applied in manure and fertilizers which may be recovered in the crops grown upon them.

In the pursuit of this research the Station is now employing nearly 900 permanently located plots, chiefly one-tenth acre in size, lying in part upon its farm near Wooster, and in part upon other tracts of land, leased for this purpose in different parts of the state.

The soils under test range from dune sand to the heaviest clay, and from land newly cleared from the forest, to that which has been robbed of its natural fertility by three-quarters of a century of an exhaustive system of husbandry.

In selecting these soils great care has been exercised to secure uniformity in character, topography and previous history of soil for each separate test. Land with a slight incline has been taken in preference to that which is absolutely level, as the excess of water collected in the slight depressions of level land tends to obscure results. Except on the dune sand and on the soil at East Liverpool, which is almost as pervious to water as the sand, all the plots have been slightly ridged in order the more uniformly to dispose of surface water and to prevent it from washing across the plots; and, with the same exceptions, and one other tract of about two acres of land, newly cleared from the forest, all the land in these experiments has been underdrained with tile drains, laid 36 feet apart and 30 inches in depth.

The land in these experiments has been laid out in plots of one-tenth, one-sixteenth or one-twentieth acre, chiefly of the larger size. The plots are 16 feet wide—this being a convenient width for our seeding and harvesting machinery—with dividing spaces 2 feet wide. The tile drains are laid under alternate dividing spaces, so that every plot has a tile drain on one side or the other. The plots are arranged in blocks of 8 or 10, and roadways 12 feet wide are left between these blocks to facilitate harvesting when, as sometimes happens, it is necessary to cut but one way, and also for convenience in hauling in the grain, as it is necessary to

avoid the repeated passing of wagons or machines over land used in experiments.

The crops employed in these tests are corn, oats, wheat, clover, timothy and potatoes; soy beans being sometimes substituted for clover in case of failure to secure a stand of the latter crop. The cereal crops, corn, oats and wheat, are grown both continuously and in rotation. Three rotations are in progress, one of corn, oats and wheat, one year each, followed by clover and timothy, two years; one of potatoes, wheat and clover, one year each, and one of corn, wheat and clover, one year each. The fertilizers are applied altogether upon the cereal and potato crops; the clover and timothy follow as gleaners.

Wherever possible, machinery is used in the planting, cultivating and harvesting of the cereal and hay crops, as the work can be more uniformly and more accurately done by machinery than by hand. The fertilizers are distributed by the fertilizer drill, for corn as well as for oats and wheat; the fertilizers for all the plots of an experiment being mixed to a uniform bulk with sand, so that all may be distributed with one setting of the drill. The manure is applied with the manure spreader. For all crops the fertilizers are distributed just before planting. The corn is planted with the double check-rower, and the oats and wheat with grain drills In sowing the small grains the space sown is a few feet longer at each end than the actual plot, and is cut back to the proper length at a later date. This is done to avoid the blanks caused by the time required for the seed to run from the hopper to the ground.

All the plots are permanently marked by iron stakes, which are set either at the corners of each plot or at those of each block, the stakes being driven to the surface of the ground so that machinery can pass over them. In planting corn, or drilling oats or wheat, a stake is set at the proper distance from the corner of the plot and the planter or drill is driven to this stake, the driver sighting over the end of the tongue. The drivers are expected to make straight rows, whether with planter or drill.

The corn is cultivated with double cultivators, ample space for turning the team (14 to 20 feet) being left at the ends of the plots. Level-working cultivators are used.

The oats and wheat are harvested with automatic binders. In cutting, a man follows the machine constantly, to see that every sheaf falls upon its proper plot, and to clean off any parts of bundles at the ends.

The corn is cut and husked by hand. The total stalks, barren stalks, ears and nubbins are counted, and the ears and nubbins are weighed separately.

The oats and wheat are threshed from the shock. Several plots are hauled in at a single load, sheets being used to separate them. The total weight of the load is taken on ordinary wagon scales; a plot is thrown off to the thresher, the load is weighed again, and so on until it is all off.

Great care is taken in threshing to insure the most accurate separation possible of the grain from the different plots. The grain is weighed from the thresher into labeled sacks and held until opportunity is had to verify the weights.

In harvesting the hay the mowing machine is driven to stakes, just as the planter and drill are in planting, the grass growing in the dividing spaces being left until after the hay on the plots is cured, weighed and hauled away. The hay has hitherto been loaded on slings, one plot to a sling and several slings to a load, the wagon being run out of the barn and weighed again after unloading each plot. A more satisfactory way, recently adopted, is to weigh the slings, either on apparatus adjusted to the track in the barn, or on a portable derrick in the field.

The potatoes have thus far been planted by hand and harvested with the help of a shovel plow, or digger of that type. They are weighed in the field, then taken to the barn, assorted into large and small and weighed again.

THE SOILS UNDER EXPERIMENT.

This work is now in progress in five sections of the state, namely:

1. At the Experiment Station, at Wooster; the soil here is a yellow, somewhat sandy clay, lying upon the upper rocks of the Waverly series; it is of glacial drift origin, but is largely modified by the soft, sandy shales upon which it lies, and which have been ground up and mixed with materials derived from granites and limestone to the northward. The native rock is abundantly streaked with iron, and a liberal percentage of iron is found in the soil, as shown by its analysis.

The original forest growth of this region was chiefly white oak, (*Quercus alba* L) with a little admixture of red, scarlet and black oaks, and an occasional chestnut (*Castanea vesca* L.). The most striking arboreal feature is the thick undergrowth of Dogwood (*Cornus florida* L.) which belts the forest with its white blossoms in early May.

The topography of the country is rolling, due entirely to erosion, as the rocks lie in level strata. When the forest was cleared away the slowly decaying roots of the deep-rooting White Oak furnished channels of drainage, through the thin sheet of clay, to the loosely stratified rocks below, and through their rifts and seams the drainage waters precolate, to feed the multitude of springs for which the region is famous. But as the roots decayed more completely the plow and the trampling of teams and pastured stock obliterated these natural channels, and artificial drainage became necessary.

In one of the fields a large system of tile drains has been led into a cistern or well, dug deeply into the shaly rock below, and which serves as a complete outlet to the drains.

2. Corn, oats and wheat are being grown in continuous culture on the farm of the Ohio State University at Columbus. The soil here is a

PLATE I.

"The rocks lie in level strata * * *
and through their rifts and seams the drainage waters percolate, to feed the springs for which this region is famous."

much heavier clay than that at Wooster, lying in part upon the Huron shale and in part upon alluvial gravels. Twenty-two plots of one-tenth acre each are devoted to each crop. The work was begun in 1888 and is continued by coöperation between the Farm Department of the University and the Experiment Station.

3. An experiment in the continuous culture of corn on the same land has been carried on since 1888 near East Liverpool, Columbiana county, by coöperation between the owner of the land and the Station. The soil there is a thin clay; the underlying rock a porous shale belonging to the coal measures.

4. A sub-station, or test farm, for field experiments, was located in 1894 near Neapolis, about 20 miles west of Toledo, on the yellow, dune sands which mark the ancient beach of Lake Erie. The native forest here is a scrubby growth of White and Black Oaks, chiefly the latter. The timber was cleared from the land for this test, the bringing of this loose sand into profitable production being the chief problem here.

5. A similar sub-station was established in 1895 near Strongsville, about 12 miles southwest of Cleveland. The underlying rock here is the Cuyahoga shale, a gray, argillaceous shale, nearly impervious to water, which weathers into a cold, heavy, tenacious, white clay. Although this region lies within the glaciated area of the state, the underlying rock, which, in the case of this test farm, is usually less than 10 feet from the surface, is the chief source from which the soil has been derived. The native forest of this region consisted chiefly of Beech (*Fagus ferruginea* Ait.) and Elm (*Ulmus Americana* L.), with Sugar Maple (*Acer saccharinum* Wang.) on the better drained portions.

In Tables I and II are given the mechanical and chemical analyses of several of these soils. From these tables it will be seen that the soils at Wooster, Strongsville and Columbus show considerable similarity in physical constitution, the most marked difference being the larger proportion of clay in the Strongsville soil. In the Neapolis soil, however, the excess of sand and deficiency of silt and clay are marked. Comparing the Neapolis with the Wooster and Strongsville soils, it will be seen that the average size of the soil particles is approximately ten times as great in the former as in the latter. The Columbus soil stands between these two classes in mechanical texture, but when we come to consider their chemical composition, as shown in Table II, we find that the soil last named is far richer in the chemical constituents of fertility than either of the others, while the sandy soil of the sub-station at Neapolis is relatively deficient.

These points are graphically brought out in Diagram I, which shows the relative proportions of phosphoric acid, potash, lime and magnesia found in the different soils. This diagram shows that the proportion of phosphoric acid is lowest in the soil at Wooster and highest in that at Strongsville; that lime and magnesia combined comprise nearly the same

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TABLE I. MECHANICAL ANALYSIS OF SOILS UNDER EXPERIMENT.

Per cent of gravel, sand, silt and clay and loss on ignition, and diameter of soil particles in millimeters.*

Soils	Grav'l 2.0 to 1.0 mm.	Co'rse sand 1.0 to 0.5 mm.	Medium sand 0.5 to 0.25 mm.	Fine sand 0.25 to 0.1 mm.	Very fine sand 0.1 to 0.05 mm.	Silt 0.05 to 0.01 mm.	Fine silt 0.01 to 0.005 mm.	Clay 0.005 to 0.0001 mm.	Loss on ignition.
First six inches—									
Wooster, E. Farm	0.56	0.86	0.71	1.79	20.47	29.97	36.07	4.74	3.73
" S. Farm	0.37	0.93	0.65	1.00	17.19	30.92	40.39	3.47	3.76
Strongsville	2.27	2.34	1.93	4.31	10.74	23.14	38.36	8.59	5.41
Columbus	0.86	2.17	2.82	8.07	18.47	26.18	28.91	6.18	4.67
Neapolis	0.00	0.66	2.17	32.60	51.60	1.93	3.36	1.26	4.49
Second six inches—									
Wooster, E. Farm	1.27	1.49	0.93	2.35	16.84	32.21	34.18	6.15	3.40
" S. Farm	0.10	0.50	0.51	1.05	20.34	32.30	32.63	8.01	3.05
Strongsville	1.46	1.83	1.85	4.25	9.49	25.59	33.64	15.68	4.18
Columbus	0.68	2.06	2.69	8.38	18.30	26.27	28.81	7.16	4.36
Neapolis	0.00	0.64	1.85	30.93	56.09	1.52	2.95	2.53	2.53

*25.4 millimeters = 1 inch.

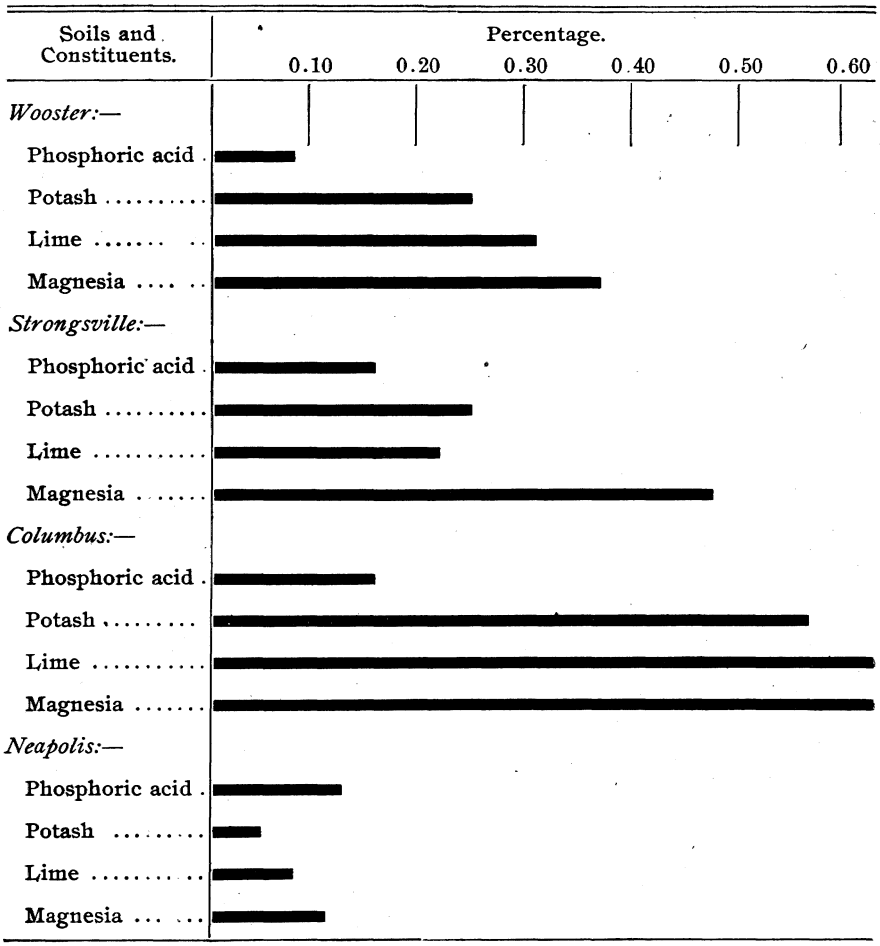
TABLE II. CHEMICAL COMPOSITION OF SOILS UNDER EXPERIMENT.

Percentage composition

Soils	Silica and insoluble matter	Potash (K_2O)	Soda (Na_2O)	Lime (CaO)	Magnesia (MgO)	Iron sesquioxide (Fe_2O_3)	Alumina (Al_2O_3)	Phosphoric acid (P_2O_5)	Sulphuric acid (SO_3)	Water and loss on ignition
Wooster, E. Farm—										
First 6 inches.....	88.713	.221	.393	.320	.361	2.643	2.533	.080	.044	4.481
Second 6 inches..	87.640	.278	.386	.307	.352	3.297	3.493	.080	.047	4.029
First 12 inches....	88.176	.250	.390	.313	.356	2.970	3.013	.080	.045	4.255
Strongsville—										
First 6 inches.....	85.045	.242	.145	.220	.432	3.010	2.535	.161	.055	7.937
Second 6 inches..	82.872	.260	.225	.190	.517	4.432	4.252	.129	.052	6.925
First 12 inches....	83.958	.251	.185	.205	.474	3.721	3.393	.145	.053	7.421
Columbus, O. S. U.—										
First 6 inches.....	83.437	.565	.739	.562	.619	3.409	4.858	.134	.089	5.869
Second 6 inches..	83.873	.562	.782	.689	.626	3.628	4.262	.152	.101	5.659
First 12 inches....	83.654	.563	.761	.621	.623	3.518	4.560	.143	.095	5.764
Neapolis—										
First 6 inches.....	92.090	.046	.060	.070	.100	1.000	1.100	.120	.030	5.130
Second 6 inches..	93.980	.040	.080	.070	.110	1.000	2.150	.110	.020	2.750
First 12 inches....	93.035	.043	.070	.070	.105	1.000	1.625	.115	.025	3.940

proportion of both these soils; that in the Columbus soil there is more than twice as much each of potash, lime and magnesia as is found at either Wooster or Strongsville, while the deficiency of the Neapolis soil in these constituents is strongly brought out.

DIAGRAM I. PERCENTAGE OF IMPORTANT SOIL CONSTITUENTS.

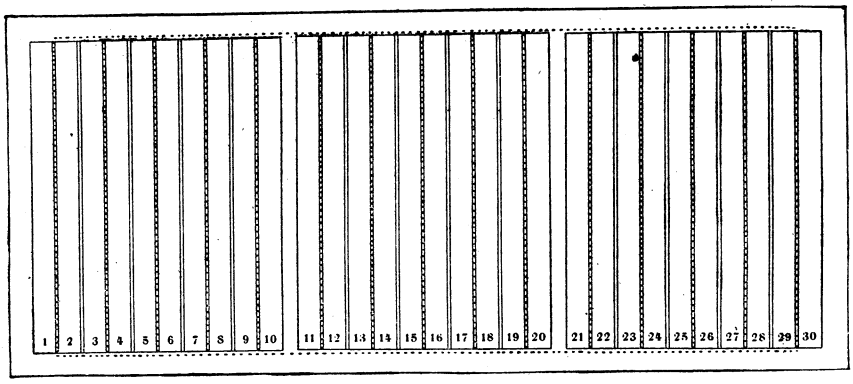


FERTILIZERS ON CROPS GROWN IN FIVE-YEAR ROTATION.

Diagram II shows the arrangement of one of the five sections, of 30 plots each, employed in the five-year rotation at Wooster. These sections, together with a similar section devoted to the continuous culture of corn, oats and wheat, 10 plots each, are arranged in two tiers, lying on the east and west sides of the "East Farm." It was not possible to locate them side by side, because of lack of suitable land. They occupy the

crests of two low ridges, running at a slight angle with the lines of the farm, as shown by the accompanying farm map.

DIAGRAM II. ARRANGEMENT OF PLOTS IN 5-YEAR ROTATION, WOOSTER.



In Diagram III is given the arrangement of the land devoted to the parallel test at Strongsville. Here a broad, uniform, gentle slope made it possible to arrange all the plots in a compact body.

Dotted lines indicate drains in this and following plans.

Table III shows the general plan of fertilizing in this rotation, and Table IV gives the total quantity of fertilizing materials applied per acre in the five years of a rotation, with estimated quantities of fertilizing constituents carried, and cost of total application. Superphosphate was used in the form of dissolved bone black previous to 1897, but since that date it has been given in acid phosphate, the 14 per cent. grade of Carolina acid phosphate being used in 1897 and 1898, and 16 per cent. Tennessee acid phosphate for the crops of 1899. When other carriers of phosphoric acid (wheat bran, slag meal, bone meal) are used the quantity applied is intended to carry the same quantity of phosphoric acid as that found in the standard dressing.

Nitrate of soda is used as the standard carrier of nitrogen, and is applied only in the spring. On corn, oats and potatoes it is used at the rate of 160 pounds per acre, and on wheat at the rate of 120 pounds, applied in April, and following a dressing of 40 pounds per acre of dried blood given in the fall. On Plot 12 in both tests the nitrate is increased to 240 pounds, and on Plots 35 and 36, at Strongsville, it is diminished to 80 and 40 pounds respectively.

Muriate of potash is used as the carrier of potash, and is applied uniformly at the rate of 80 pounds per acre on corn and oats and 100 pounds on wheat, except on Plots 17 and 21, where allowance is made for the potash in the bran and oil-meal; on Plot 30, where it is used at the

DIAGRAM III. ARRANGEMENT OF PLOTS IN 5-YEAR ROTATION, NORTH-EASTERN SUB-STATION, STRONGSVILLE.

Plots one-tenth aere.

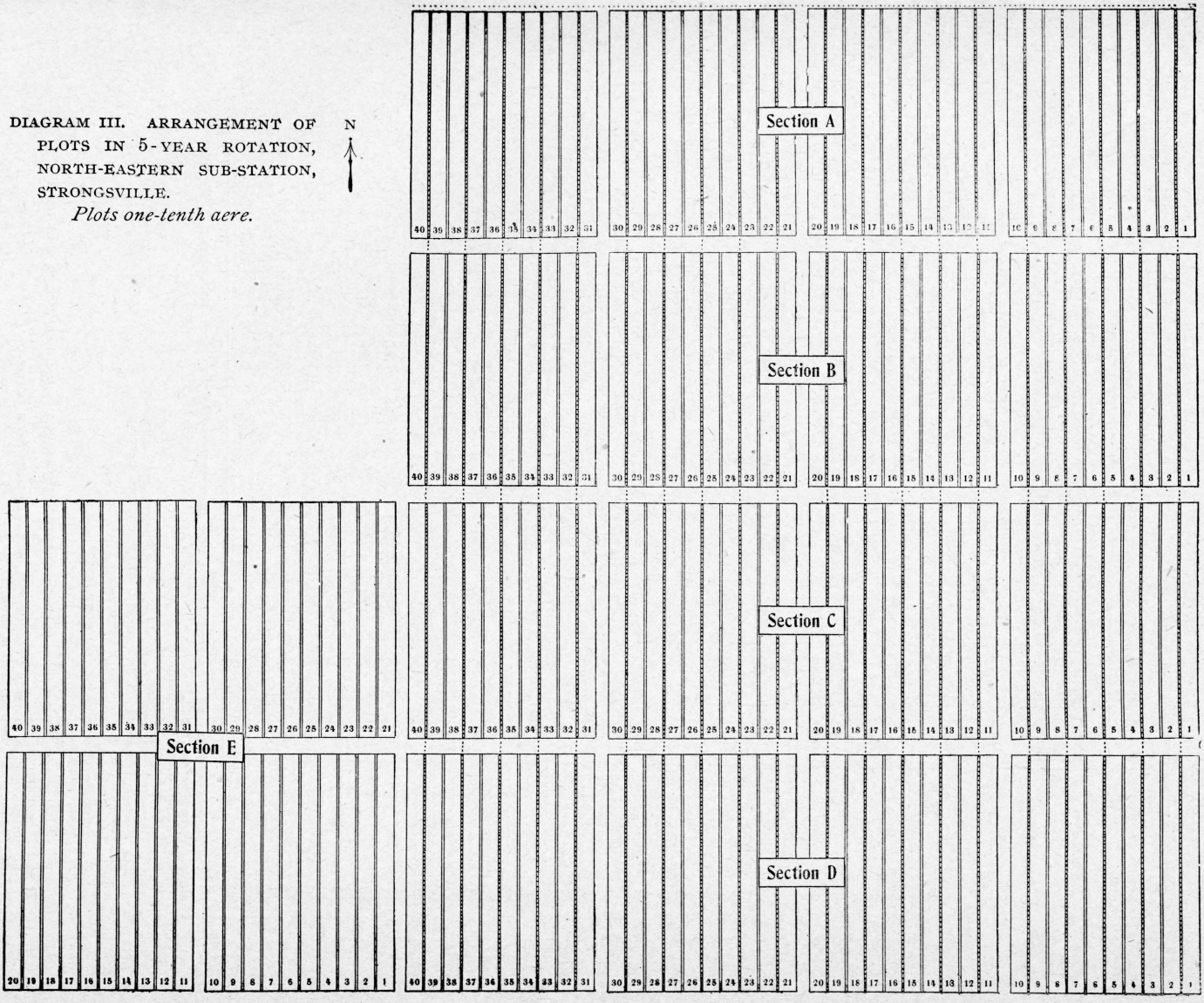


TABLE III. PLAN OF FERTILIZING IN 5-YEAR ROTATION

Fertilizers in pounds per acre.

Plot No.	On Corn			On Oats			On Wheat			
	Superphosphate [1]	Muriate of potash	Nitrate of soda	Superphosphate [1]	Muriate of potash.	Nitrate of soda	Superphosphate [1]	Muriate of potash	Dried blood	Nitrate of soda [2]
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	80	.....	.....	80	.....	.....	160	.....	.....	.....
3	.....	80	.....	.....	80	.....	.....	100	.....	.....
4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	.....	.....	160	.....	.....	160	.....	.....	40	120
6	80	.....	160	80	.....	160	160	.....	40	120
7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	80	80	.....	80	80	.....	160	100	.....	.....
9	.....	80	160	.....	80	160	.....	100	40	120
10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
11	80	80	160	80	80	160	160	100	40	120
12	80	80	240	80	80	240	160	100	40	200
13	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
14	80	80	160	.....	.....	.....	160	100	40	120
15	.....	.....	.....	.....	.....	.....	160	100	40	120
16	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
17	A	65	80	A	65	80	B	70	.....	.....
18	C	.....	.....	.....	.....	.....	C	.....	.....	.....
19	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
20	D	.....	.....	.....	.....	.....	D	.....	.....	.....
21	30	70	E	30	70	E	110	90	E	.....
22	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
23	70	80	F	70	80	F	140	100	200	.....
24	80	80	G	80	80	G	160	100	G	.....
25	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
26	H	80	150	H	80	150	I	100	.....	135
27	K	80	160	K	80	160	K	100	40	120
28	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
29	L	80	160	L	80	160	L	100	40	120
30	100	10	M	.....	.....	.....	100	10	M	.....
31	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
32	80	80	80	80	80	80	160	100	25	60
33	80	80	40	80	80	40	160	100	15	30
34	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
35	80	40	160	80	40	160	160	50	40	120
36	80	20	160	80	20	160	160	25	40	120
37	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
38	.....	.....	.....	.....	.....	.....	200	20	N	.....
39	.....	.....	.....	.....	.....	.....	O	.....	.....	.....
40	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

[1] Superphosphate as dissolved bone-black previous to 1897; as acid phosphate, 1897 and since. [2] Applied in April.

A. Wheat bran, 500 pounds.
B. Wheat bran, 1,000 pounds.
C. Barnyard manure, 16,000 pounds, on wheat and corn only.
D. Barnyard manure, 8,000 pounds, on wheat and corn only.
E. Linseed oil-meal, 500 pounds.
F. Dried blood, 200 pounds.
G. Sulphate of ammonia, 120 pounds.
H. Raw bone meal, 55 pounds.
I. Raw bone meal, 110 pounds.
K. Acid phosphate previous to 1897; dissolved bone-black since. phosphoric acid on Plots 11 and 27 equivalent.
L. Basic slag, 65 pounds on corn and oats, 130 pounds on wheat.
M. Tankage, 7 and 30, 100 pounds.
N. Tankage, 7 and 30, 200 pounds.
O. Barnyard manure, 32,000 pounds, on wheat only.

TABLE IV. FERTILIZERS ON CROPS GROWN IN FIVE-YEAR ROTATION.

Total quantity of fertilizing materials applied per acre during the five years of a rotation, with fertilizing constituents carried and cost of total application.

Pl't No.	Fertilizing materials					Fertilizing constituents			
	Superphosphate	Muriate of potash	Nitrate of soda	Dried blood	Total	Phosphoric acid	Potash	Nitrogen	Cost of fertilizers
	Pounds	Pounds		Pounds	Pounds	Pounds	Pounds	Pounds	
2	320	.....	.....	.....	320	50	.....	.....	$2 40
3	.....	260	.....	.....	260	.....	130	.....	6 50
5	.....	.....	440	40	480	.....	.....	75	12 00
6	320	.....	440	40	800	50	.....	75	14 40
8	320	260	.....	.....	580	50	130	.....	8 90
9	.....	260	440	40	740	.....	130	75	18 50
11	320	260	440	40	1,060	50	130	75	20 90
12	320	260	680	40	1,300	50	130	112	26 90
14	240	180	280	40	740	38	90	50	14 30
15	160	100	120	40	420	25	50	25	7 70
17	A	200	120	40	.....	50	130	75	19 00
18	B	.....	.....	.....	32,000	66	170	150	8 00
20	B	.....	.....	.....	16,000	33	85	75	4 00
21	170	230	C	.....	1,900	51	135	81	.....
23	320	260	.....	600	1,180	50	130	75	.....
24	320	260	D	.....	940	50	130	74	.....
26	E	260	435	.....	915	50	130	77	.....
27	F	260	440	40	1,080	50	130	75	.....
29	G	260	440	40	1,000	50	130	75	.....
30	200	20	H	.....	420	50	10	12	3 75
32	320	260	60	25	820	50	130	38	14 90
33	320	260	30	15	700	50	130	19	11 90
35	320	130	120	40	930	50	65	75	17 65
36	320	65	120	40	865	50	32	75	16 03
38	200	20	H	.....	420	50	10	12	3 75
39	B	.....	.....	.....	32,000	66	170	150	8 00

A Wheat bran, 2,000 pounds, 1894–98.
B Barnyard manure from horses.
C Linseed oil-meal, 1,500 pounds.
D Sulphate of ammonia, 360 pounds.
E Bone meal, 220 pounds.
F Acid phosphate, 840 pounds, 1894–96. Dissolved bone black, 280 pounds, 1897.
G Basic slag, 260 pounds.
H Tankage, (7 and 30) 200 pounds. Superphosphate as acid phosphate.

rate of ten pounds only, and on Plots 35 and 36, at Strongsville, where the quantity is reduced to 40 and 20 pounds respectively.

On Plot 17 wheat bran is used as the carrier of all the phosphoric acid and part of the nitrogen and potash, and on Plot 21 linseed oil-meal is used as the carrier of all the nitrogen and part of the phosphoric acid and potash. On Plot 23 dried blood, and on Plot 24 sulphate of ammonia is substituted for nitrate of soda. On Plot 26 raw bone meal is used as the carrier of the phosphoric acid and part of the nitrogen, the total nitrogen being brought up, by the addition of nitrate of soda, to the quanity used on other standard plots. On Plot 27 acid phosphate has been used as the carrier of phosphoric acid previous to 1897, and dissolved bone-black since, this plot being compared with Plot 11. On Plot 29 basic slag is used as the carrier of phosphoric acid. On Plot 30 is used a mixed fertilizer, having approximately the composition of the best ready-mixed fertilizers sold in the state. For the crops of 1894 and 1895, at the Central Station, this fertilizer was mixed from dissolved bone-black, nitrate of soda and muriate of potash. In 1895 a ready-mixed fertilizer, having approximately the same analysis ("Ammonia 3 to 4 per cent., phosphoric acid 8 to 10 per cent., potash 2 to 2½ per cent.") was used at Strongsville, and in 1896 and since, the fertilizer has been mixed from tankage, acid phosphate and muriate of potash for both experiments.

In the tests herein reported the corn was grown on old sod land at Strongsville and Wooster in 1894, and on land that had grown cowpeas and clover the preceding season at Wooster in 1895 and 1896. In 1897 it followed clover and timothy at Wooster and navy beans at Strongsville.

The land at Wooster was underdrained in 1893 by tile drains laid 36 feet apart. That at Strongsville had not been drained previous to 1897, but was plowed in narrow lands, giving partial surface drainage. The season of 1895 was dry and the crop was exceptionally good for that land, but in 1896 it suffered from excess of rain. In 1897 all the land at Strongsville was drained except Section E.

In both 1895 and 1896 the wheat crop on the thin land on which this test is located at the Central Station suffered severely from winter killing, followed by spring drouth, the average yield of the unfertilized plots falling to three bushels per acre in 1895, and to one bushel in 1896. The destruction of crop was only partially prevented by fertilizers. On the heavy clay of the sub-station the wheat was so completely destroyed that no attempt was made to harvest it separately; the most heavily fertilized plots showed but little if any more wheat than the unfertilized plots at the Central Station.

There have been thus far harvested at Wooster in these experiments 5 crops of corn, 6 each of oats and wheat and 8 of hay, 4 of the first year's growth—chiefly clover, and 4 of the second year—chiefly timothy. The clover which should have made the first year's harvest for 1899 was destroyed by the severe winter, and soy beans were sown instead.

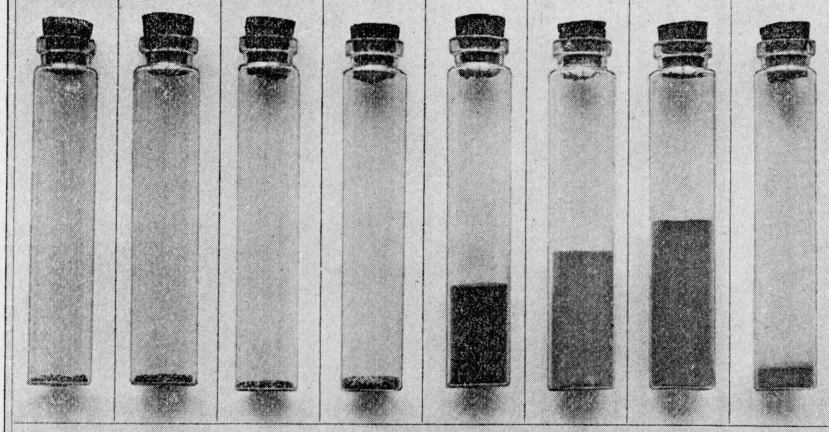
OHIO AGRICULTURAL EXPERIMENT STATION.

CHEMICAL DEPARTMENT.

Character of Soils of Station East Farm, Wooster, O.

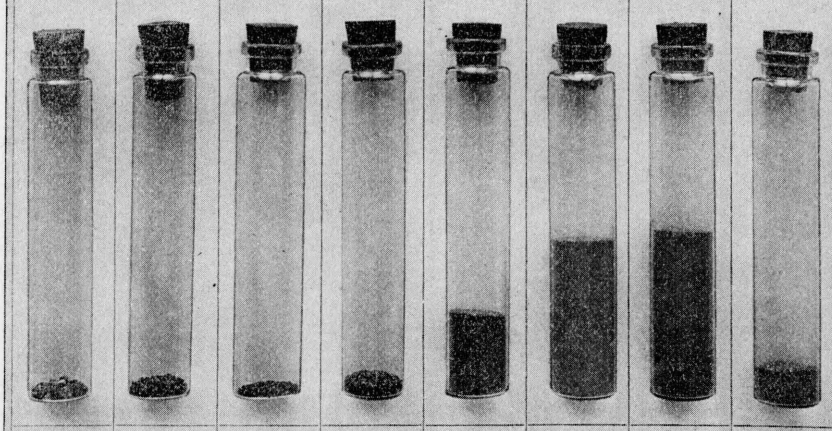
Per cent of Gravel, Sand, Silt, and Clay in 20 Grams of Soil.

Gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Fine silt.	Clay.
0.56	0.86	0.71	1.79	20.47	29.97	36.07	4.74



Per cent of Gravel, Sand, Silt, and Clay in 20 Grams of Sub-Soil.

1.27	1.49	0.93	2.35	16.84	32.21	34.18	6.15



2.0-1.0 mm.	1.0-0.5 mm.	.5-.25 mm.	.25-.1 mm.	.1-.05 mm.	.05-.01 mm.	.01-.005 mm.	.005-.0001 mm.

DIAMETER OF SOIL PARTICLES IN MILLIMETERS.

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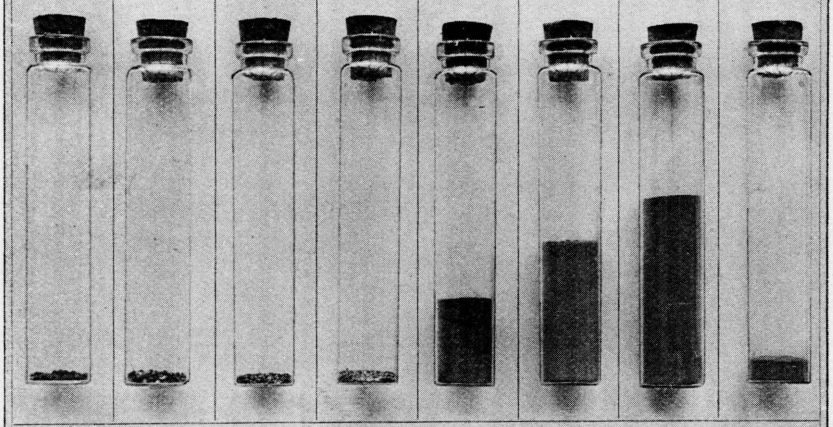
OHIO AGRICULTURAL EXPERIMENT STATION.

CHEMICAL DEPARTMENT.

Character of Soils of Station South Farm, Wooster, O.

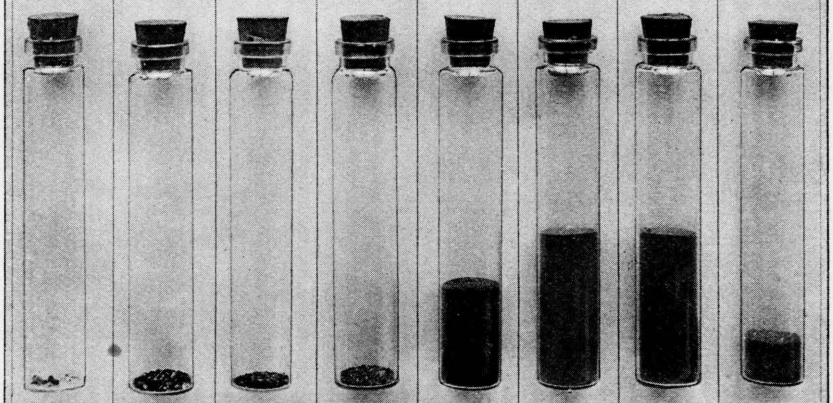
Per cent of Gravel, Sand, Silt, and Clay in 20 Grams of Soil.

Gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Fine silt.	Clay.
0.37	0.93	0.65	1.00	17.19	30.92	40.39	3.47



Per cent of Gravel, Sand, Silt, and Clay in 20 Grams of Sub-Soil.

0.10	0.50	0.51	1.05	20.34	32.30	32.63	8.01



2.0-1.0 mm.	1.0-0.5 mm.	.5-.25 mm.	.25-.1 mm.	.1-.05 mm.	.05-.01 mm.	.01-.005 mm.	.005-.0001 mm.

DIAMETER OF SOIL PARTICLES IN MILLIMETERS.

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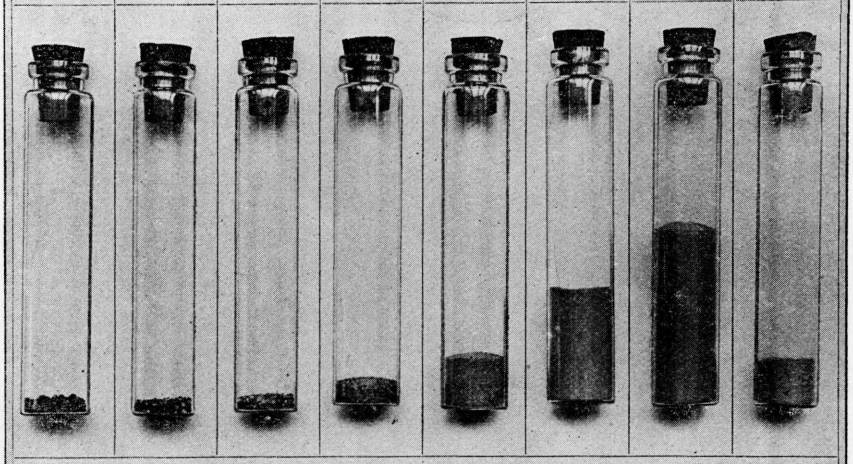
OHIO AGRICULTURAL EXPERIMENT STATION.

CHEMICAL DEPARTMENT.

Character of Soils of Northeastern Substation Farm, Strongsville, O.

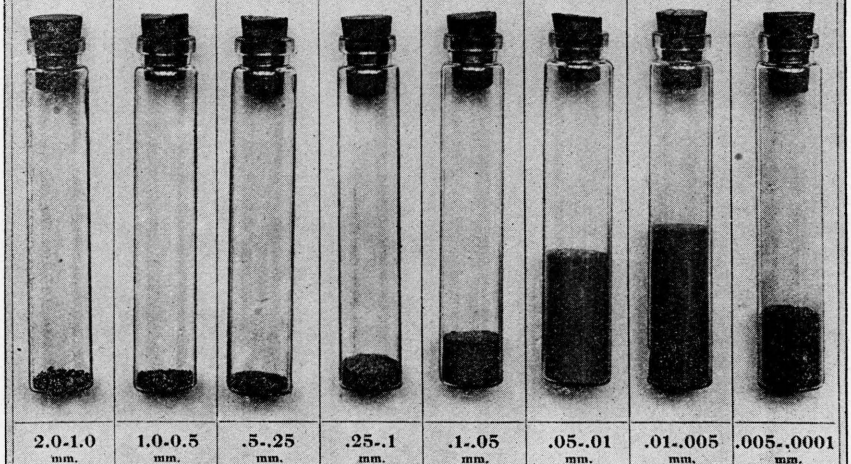
Per cent of Gravel, Sand, Silt, and Clay in 20 Grams of Soil.

Gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Fine silt.	Clay.
2.27	2.34	1.93	4.31	10.74	23.14	38.36	8.59



Per cent of Gravel, Sand, Silt, and Clay in 20 Grams of Sub-Soil.

1.46	1.83	1.85	4.25	9.49	25.59	33.64	15.68



2.0-1.0 mm.	1.0-0.5 mm.	.5-.25 mm.	.25-.1 mm.	.1-.05 mm.	.05-.01 mm.	.01-.005 mm.	.005-.0001 mm.

DIAMETER OF SOIL PARTICLES IN MILLIMETERS.

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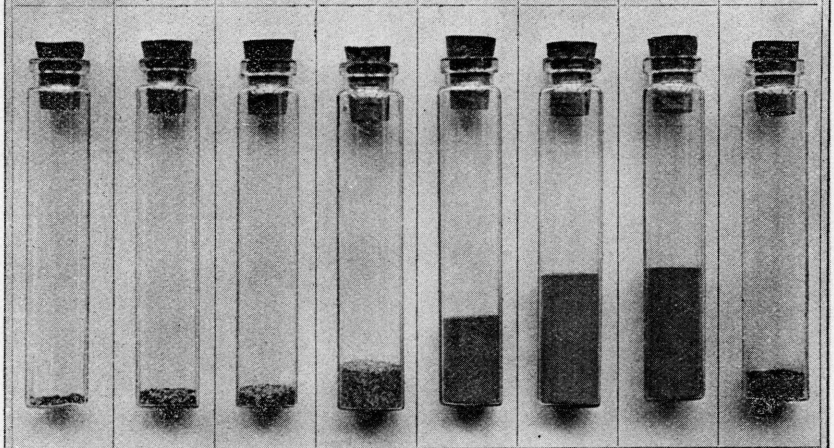
OHIO AGRICULTURAL EXPERIMENT STATION.

CHEMICAL DEPARTMENT.

Character of Soils of North Field, Ohio State University Farm, Columbus, O.

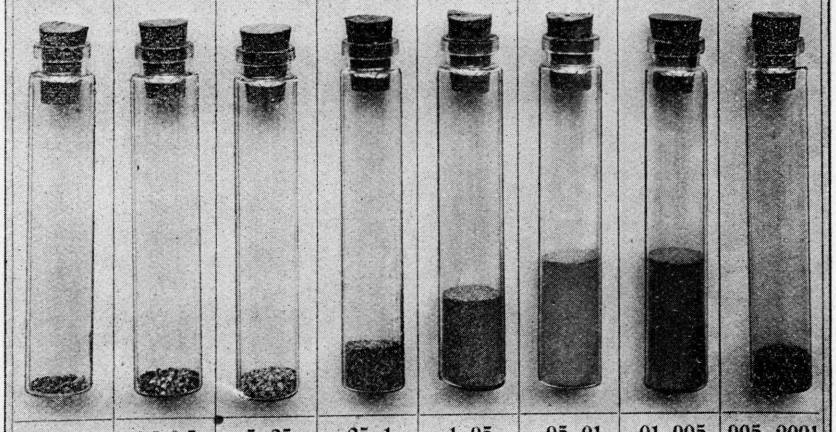
Per cent of Gravel, Sand, Silt, and Clay in 20 Grams of Soil.

Gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Fine silt.	Clay.
0.86	2.17	2.82	8.07	18.47	26.18	28.91	6.18



Per cent of Gravel, Sand, Silt, and Clay in 20 Grams of Sub-Soil.

0.68	2.06	2.69	8.38	18.30	26.27	28.81	7.16



2.0-1.0 mm.	1.0-0.5 mm.	.5-.25 mm.	.25-.1 mm.	.1-.05 mm.	.05-.01 mm.	.01-.005 mm.	.005-.0001 mm.

DIAMETER OF SOIL PARTICLES IN MILLIMETERS.

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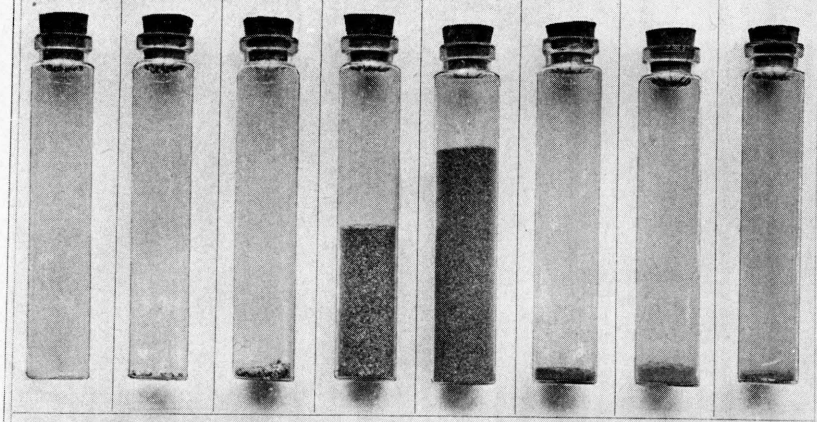
OHIO AGRICULTURAL EXPERIMENT STATION.

CHEMICAL DEPARTMENT.

Character of Soils of Northwestern Substation Farm, Neapolis, O.

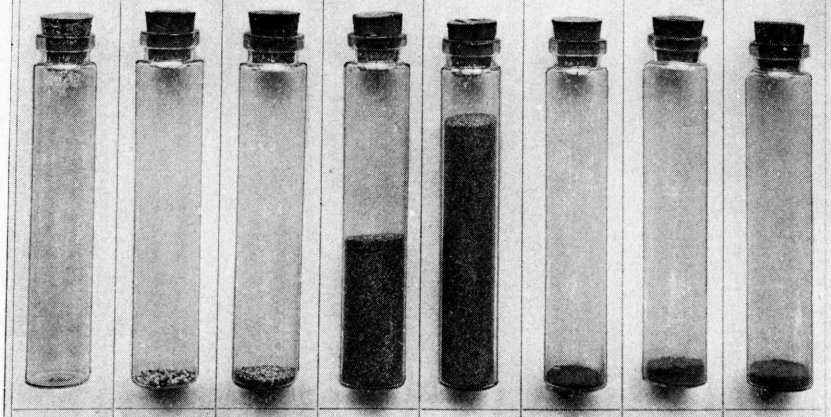
Per cent of Gravel, Sand, Silt, and Clay in 20 Grams of Soil.

Gravel.	Coarse sand.	Medium sand.	Fine sand.	Very fine sand.	Silt.	Fine silt.	Clay.
0.00	0.66	2.17	32.60	51.60	1.93	3.36	1.26



Per cent of Gravel, Sand, Silt, and Clay in 20 Grams of Sub-Soil.

0.00	0.64	1.85	30.93	56.09	1.52	2.95	2.53



2.0-1.0 mm.	1.0-0.5 mm.	.5-.25 mm.	.25-.1 mm.	.1-.05 mm.	.05-.01 mm.	.01-.005 mm.	.005-.0001 mm.

DIAMETER OF SOIL PARTICLES IN MILLIMETERS.

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At Strongsville 4 crops of corn, 4 of oats, 3 of wheat and 3 of the first-year hay have been harvested. The first crop of wheat was completely destroyed by the severe winter of 1895-6, and the second-year hay crops have been so weedy that no safe deductions could be drawn from them.

Tables V and VI give the average annual increase from the fertilizers, as found in these tests, the statistics of actual yield being given in the Appendix.

These tables agree in giving to phosphoric acid distinctly the first place as a crop increaser on both soils, as shown by the marked increase of yield on Plot 2. In both tests the increase from potash, when used alone, is relatively small, amounting to practically nothing at Strongsville. The effect of nitrogen alone, or nitrogen with potash, is very small in both tests, but is considerably greater at Wooster than at Strongsville. A possible explanation of this difference lies in the fact that the test at Strongsville is located upon land which had lain in pasture for twenty years or more, having first been exhausted by cropping, while that at Wooster had had no such respite, having, for a like period been delivered over to the tenant farmer, under the system of annual lease which prevails in Ohio, with little or no restriction upon the tenant's liberty to despoil the land by continuous cropping without manure.

While there are as yet some minor differences in the relative effect of the various fertilizing constituents on the two soils under consideration, their differences seem to be merely variations in degree of similar effect, and therefore a consolidation of the results of the two experiments seems to be perfectly legitimate, and likely to be of wider application, as a guide to the use of fertilizers, than the results of either test taken separately. Such a consolidation is made in Diagram IV, in which an attempt is made to show the value of the increase obtained from the various fertilizers, with the proportion of the total value found in each of the crops, taking the crops at their approximate market value during recent years. In compiling this diagram ear-corn has been valued at 50 cents per cental or 35 cents per bushel; oats at 80 cents per cental, or 25.6 cents per bushel; wheat at $1.10 per cental, or 66 cents per bushel; corn stover at $3.00 per ton, oat and wheat straw at $2.00 and mixed hay at $6.00 per ton. The cost of the fertilizer is shown by the heavy black lines. At these valuations the cost of the fertilizer has been repaid in every case where phosphoric acid was used except on Plot 12; here the large application of costly nitrogen caused the cost of the fertilizer to exceed the value of the increased produce.

Of the plots receiving phosphoric acid, potash and nitrogen singly, Plot 2, receiving phosphoric acid only, shows very much the largest increase and gives a handsome profit, owing in part to the relatively low cost of the fertilizer. On Plots 3 and 5, receiving potash and nitrogen respectively, the increase is insignificant and is procured at a heavy

2 Ex. Sta. Bul. 110.

TABLE V: INCREASE FROM FERTILIZERS IN 5-YEAR ROTATION AT WOOSTER.

Plot	Total fertilizers applied during one rotation.	Average increase in pounds per acre.								
		Corn		Oats		Wheat		Hay		Total
		Ear-corn	Sto-ver	Grain	Straw	Grain	Straw	1st year	2d year	
2	Superphosphate,[1] 320 lbs.	277	3	210	156	216	423	461	65	1811
3	Muriate of potash, 260 lbs.	188	73	65	.....	101	177	94	315	1013
5	Nitrate of soda, 440 lbs.; dried blood, 40 lbs.	163	59	114	75	97	220	104	298	1130
6	Superphosphate, 320 lbs.; nitrate,[2] 440 lbs.; blood,[3] 40 lbs.	675	217	317	367	453	906	1066	617	4618
8	Superphosphate, 320 lbs.; muriate of potash, 260 lbs.	425	285	259	322	355	511	806	324	3287
9	Muriate of potash, 260 lbs.; nitrate, 440 lbs.; blood, 40 lbs.	104	161	77	124	137	250	366	223	1442
11	Superphos., 320 lbs.; potash,[4] 260 lbs.; nitrate, 440 lbs.; blood, 40 lbs.	750	323	464	675	708	1413	1023	762	6118
12	Superphos., 320 lbs.; potash, 260 lbs.; nitrate, 680 lbs.; blood, 40 lbs.	706	293	495	785	749	1518	1172	443	6161
14	Superphos., 240 lbs.; potash, 180 lbs.; nitrate, 280 lbs.; blood, 40 lbs.	730	340	210	312	581	1254	1058	565	5050
15	Superphos., 160 lbs.; potash, 100 lbs.; nitrate, 120 lbs.; blood, 40 lbs.	*414	*138	*33	*91	533	1076	594	280	2483
17	Wheat bran, 2000 lbs.; potash, 200 lbs.; nitrate, 160 lbs.	461	165	340	485	366	725	923	360	3825
18	Barnyard manure, 16,000 lbs.	703	407	200	349	311	802	1407	1105	5284
20	Barnyard manure, 8,000 lbs.	497	300	119	212	220	539	863	760	3510
21	Superphos., 170 lbs.; potash, 230 lbs.; linseed oil-meal, 1,500 lbs.	501	292	301	505	653	1348	924	418	4942
23	Superphos., 280 lbs.; potash, 260 lbs.; dried blood, 600 lbs.	540	265	389	369	517	999	946	417	4445
24	Superphos., 320 lbs.; potash, 260 lbs.; sulphate ammonia, 360 lbs.	682	363	471	646	552	1064	792	238	4808
26	Bone meal, 220 lbs.; potash, 260 lbs.; nitrate soda, 435 lbs.	435	314	388	368	528	1109	953	636	4731
27	Acid phosphate, 320 lbs.; potash, 260 lbs.; nitrate, 480 lbs.; blood, 40 lbs.	440	214	430	544	589	1125	667	467	4546
29	Slag phosphate, 260 lbs.; potash, 260 lbs.; nitrate, 480 lbs.; blood, 40 lbs.	573	332	365	490	566	1150	845	950	5271
30	Superphos., 200 lbs.; potash, 20 lbs.; 7 and 30 tankage, 200 lbs.	421	124	164	192	323	627	780	890	3521

1 Superphosphate from dissolved bone black previous to spring of 1897, from acid phosphate since.
2 "Nitrate"= nitrate of soda in all cases.
3 "Blood"= dried blood " "
4 "Potash"= muriate of potash " "
5 Dissolved bone black, 1897 and since.
*Two years

TABLE VI. INCREASE (OR DECREASE—) FROM FERTILIZERS IN 5-YEAR ROTATION AT STRONGSVILLE

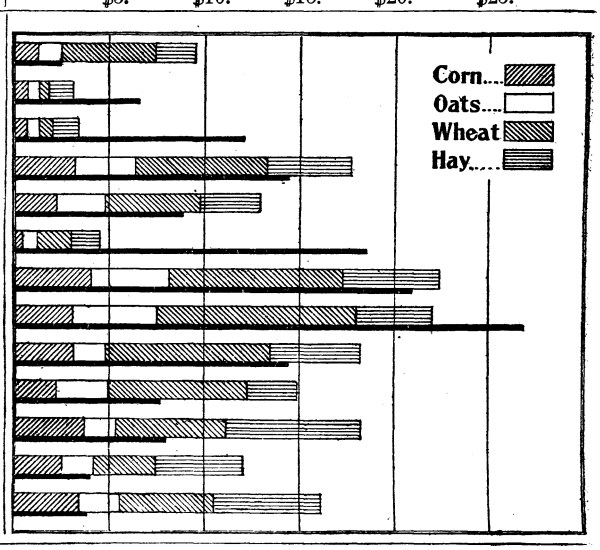
Plot	Total fertilizers applied during one rotation.	Average increase in pounds per acre							
		Corn		Oats		Wheat		Hay	Total
		Ear corn	Stover.	Grain	Straw	Grain	Straw	1st y'r	
2	Superphosphate,[1] 320 lbs	217	–12	308	315	450	990	911	3179
3	Muriate of potash, 260 lbs	48	–23	61	57	–38	–111	72	66
5	Nitrate of soda, 440 lbs.; dried blood, 40 lbs	70	5	6	117	–23	–52	238	361
6	Superphosphate, 320 lbs.; nitrate,[2] 440 lbs.; blood,[3] 40 lbs	470	21	425	490	673	1208	626	4113
8	Superphosphate, 320 lbs.; muriate of potash, 260 lbs	262	–175	333	415	473	769	676	2753
9	Muriate of potash, 260 lbs.; nitrate of soda, 440 lbs.; blood, 40 lbs	30	–68	57	19	139	285	238	872
11	Superphos., 320 lbs.; potash,[4] 260 lbs.; nitrate, 440 lbs.; blood, 40 lbs	684	220	389	362	739	1141	800	4535
12	Superphos., 320 lbs.; potash, 260 lbs.; nitrate, 680 lbs.; blood, 40 lbs	522	225	422	579	997	1850	560	5155
14	Superphos., 240 lbs.; potash, 180 lbs.; nitrate, 280 lbs.; blood, 40 lbs	288	175	147	152	826	1409	950	3947
15	Superphos., 160 lbs.; potash, 100 lbs.; nitrate, 120 lbs.; blood, 40 lbs	.....	.....	.....	.....	666	1096	594	.....
17	Wheat bran, 2000 lbs.; potash, 200 lbs.; nitrate, 160 lbs	200	12	351	584	354	598	748	2847
18	Barnyard manure, 16,000 lbs	588	136	187	238	710	1268	1006	4133
20	Barnyard manure, 8,000 lbs	393	61	100	168	430	720	629	2501
21	Superphos., 170 lbs.; potash, 230 lbs.; linseed oil-meal, 1,500 lbs	255	96	338	622	537	968	708	3524
23	Superphos., 280 lbs.; potash, 260 lbs.; dried blood, 600 lbs	402	–22	415	782	611	1108	1073	4369
24	Superphos., 320 lbs.; potash, 260 lbs.; sulphate ammonia, 360 lbs	399	112	437	693	662	1208	884	4395
26	Bone meal, 220 lbs.; potash, 260 lbs.; nitrate soda, 435 lbs	309	203	451	471	770	1304	1039	4547
27	Acid phosphate,[5] 320 lbs.; potash, 260 lbs.; nitrate, 440 lbs.; blood, 40 lbs	464	227	436	627	574	933	591	3852
29	Slag phosphate, 260 lbs.; potash, 260 lbs.; nitrate, 440 lbs.; blood, 40 lbs	626	148	448	584	878	1473	973	5130
30	Superphos., 200 lbs.; potash, 20 lbs.; 7 and 30 tankage, 200 lbs	847	165	369	414	672	1157	1173	4797
32	Superphos., 320 lbs.; potash, 260 lbs.; nitrate, 220 lbs.; blood, 25 lbs	512	84	408	502	684	1140	1032	4362
33	Superphos., 320 lbs.; potash, 260 lbs.; nitrate, 110 lbs.; blood, 15 lbs	522	28	386	598	511	628	1251	3924
35	Superphos., 320 lbs.; potash, 130 lbs.; nitrate, 440 lbs.; blood, 40 lbs	361	110	425	621	685	1117	878	4197
36	Superphos., 320 lbs.; potash, 65 lbs.; nitrate, 440 lbs.; blood, 40 lbs	650	338	413	496	731	1294	1079	5001
38	Superphos., 200 lbs.; potash, 20 lbs.; 7 and 30 tankage, 200 lbs	.....	.....	.....	.....	603	1111	1057	.....
39	Barnyard manure, 32,000 lbs., on wheat only	.....	.....	.....	.....	344	550	663	.....

1 Superphosphate from dissolved bone black previous to spring of 1897, from acid phosphate since.
2 "Nitrate"=nitrate of soda in all cases.
3 "Blood"=dried blood in all cases.
4 "Potash"=muriate of potash in all cases.
5 Dissolved bone black, 1897 and since.
* Two years.

DIAGRAM IV.—FERTILIZERS APPLIED PER ACRE ON CROPS GROWN IN FIVE-YEAR ROTATION AND VALUE OF INCREASE PER ACRE.

Average of nine rotations.

Plot No.	Total fertilizers applied in five years: Super-phosphate	Muriate of potash	Nitrate of soda*
	Pounds	*Pounds*	*Pounds*
2	320	...	...
3	...	260	...
5	...	..	480
6	320	...	480
8	320	260	...
9	...	260	480
11	320	260	480
12	320	260	720
14	240	180	320
15	160	100	160
18	Barnyard manure, 16 tons		
20	Barnyard manure, 8 tons		
30	Acid phosphate, 200 lbs.; 7-30 tankage.... 200 lbs.; Muri'te of potash 20 lbs.		



*Nitrate of soda and dried blood.

financial loss, which becomes still greater on Plot 9, receiving these two constituents in combination, but no phosphoric acid.

Plot 6 shows an increase nearly double that found on Plot 2, and much greater than the combined increase from Plots 2 and 5, but the margin of profit is narrowed because of the high cost of the nitrogen. The increase on Plot 8 is practically equal to the combined increase of Plots 2 and 3, but here again the profit is reduced because of the comparatively high cost of the potash.

The increase of Plot 11, receiving the complete fertilizer, is much greater than the combined increase from the same quantities of fertilizing materials used separately, but the profit is almost obliterated by the cost of the fertilizers.

On Plots 14 and 15 the attempt is made to extend the effect of the fertilizers by increasing the time between applications, thus giving greater opportunity to secure the full residual effect. The result is a diminished total increase, but an increasing margin of profit, until on Plot 15, fertilized only once in five years, on the wheat crop, we have a total increase amounting in average value to nearly $15.00 per acre, produced

at a cost of but little more than half that amount, by a complete fertilizer, carrying all three of the leading constituents; the net profit being the same as that found on Plot 2.

Passing the two manured plots, we find on Plot 30 the largest net profit shown by any plot in the series. This plot receives practically the same quantity of available phosphoric acid as that given to Plot 2, and in addition a small quantity each of nitrogen and potash, the nitrogen being conveyed in the comparatively cheap carrier of slaughter-house tankage. The total application to this plot is 420 pounds in the five years, divided between the corn and wheat crops, carrying 50 pounds of phosphoric acid, 10 pounds of potash and 12 pounds of nitrogen, and costing $3.75. Plot 15 receives, during the same period, an application of the same quantity of fertilizer, carrying 25 pounds each of phosphoric acid and nitrogen and 50 pounds of potash, and costing $7.75. It is evident that, in the present condition of the soils under test, it is more profitable to use more phosphoric acid and less potash, and probably also less nitrogen than is being given to Plot 15; and yet, even when clover forms a regular part of the rotation, it is profitable to add some nitrogen to the fertilizer. This last point is again illustrated by comparing Plots 8 and 15. Plot 8 receives two and one-half times as much potash as Plot 15; it also receives twice as much phosphoric acid, which all this work shows to be the dominant constituent of fertility on the soils under test, but it gets no nitrogen except that furnished by the clover. The total cost of its fertilizing is considerably greater than that of Plot 15, yet its total increase is decidedly smaller.

This point is again brought out by comparing Plots 6 and 8. The substitution of the nitrogen of Plot 6 for the potash of Plot 8 produces a marked increase of yield, yet the large gain of Plot 11 over Plot 6 shows that potash cannot be entirely dispensed with if the highest yield is to be obtained.

It appears to be clear, therefore, that under the conditions of this experiment, which is made on soils of reduced fertility, and on which there has been no systematic culture of leguminous crops, previous to the beginning of this test, we are not maintaining in the soil a supply of nitrogen sufficient for maximum crop production by simply growing one crop of clover in five years, the roots of which only are left in the soil, the tops being made into hay and removed from the land.

It also appears to be equally clear that, while the present demand for potash, by the soils under consideration, is less urgent than that for phosphoric acid and nitrogen, yet the aid of potash cannot be entirely dispensed with if the largest production is to be attained.

In the lines showing the effect of barnyard manure—Plots 18 and 20—the cost of the manure is estimated at 50 cents per ton, a sum much more than sufficient to cover the wages of man and team for the time required to move it from the barnyard to the field and spread it there, on

the ordinary farm.* If the manure is to be bought and then hauled several miles its cost may easily exceed that of a dressing of commercial fertilizers producing an equivalent effect.

In comparing the effect of the barn-yard manure with that of the commercial or chemical fertilizers, it will be seen that while the latter produce a relatively greater increase in the grain crops, the grass crops show greater benefit from the manure.

The diagram shows that the larger total increase and the greater net profit have come from the larger application of manure, but the larger profit per ton of manure has come from the smaller application; the 16 tons of manure on Plot 18 having produced an increase worth $18.00, or $1.12 per ton; whereas the 8 tons applied to Plot 20 has produced increase worth $12.00, or $1.50 per ton.† These estimates, it will be observed, are based upon very low prices of produce.

FERTILIZERS ON POTATOES AND WHEAT GROWN IN ROTATION WITH CLOVER.

An experiment in the culture of potatoes, wheat and clover in a three-year rotation is in progress at the Central Station at Wooster, and at the sub-stations at Strongsville and Neapolis, having been commenced at Wooster and Neapolis in 1894 and at Strongsville in 1895. At the Central Station at Wooster the test is located on the "South Farm," the soil of which does not differ materially in mechanical texture or chemical composition from that of the adjoining "East Farm," on which the 5-year rotation, previously considered, is located, but this farm had not been subjected to such exhaustive cropping, previous to the beginning of the test, as had the East Farm, and it was therefore in a much better condition of fertility.

The general plan of this experiment, shown in Table VII, is essentially the same as that of the 5-year rotation, the only important difference being that in the potato rotation the total application of fertilizers is considerably increased on Plots 14 and 15, instead of being decreased, as in the cereal rotation.

At the Central Station 6 crops of potatoes, 5 of wheat and 4 of clover have been harvested in this experiment, and 4 of potatoes and three of wheat at the Strongsville sub-station. One crop each of potatoes and wheat has been lost at the sub-station because of unfavorable weather

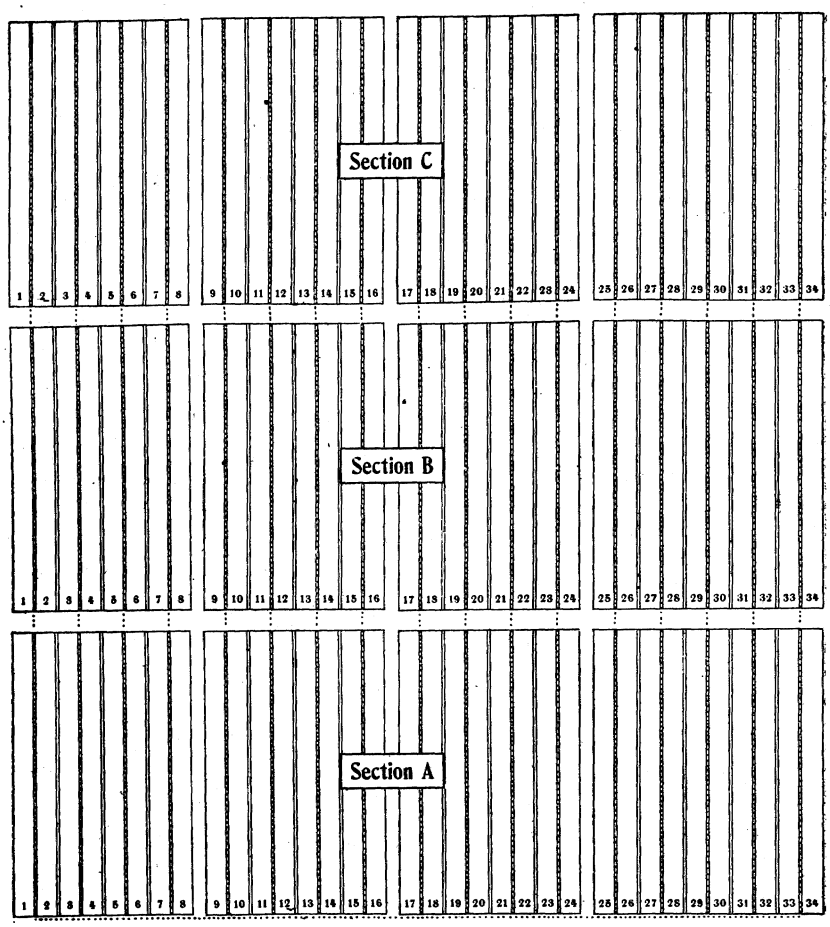
*At this Station 12 acres of land is annually top-dressed with barnyard manure, the manure being applied with a manure spreader, at the rate of 9 tons per acre, after the land has been plowed for wheat. Our books show that one man with a team has taken 108 tons of manure from the barnyard and distributed it uniformly over the field in 9 days time, or 12 tons per day. At $3.00 per day for man and team the cost of this application would be 25 cents per ton, or $2.25 per acre.

† On the assumption that the increase in the second-year hay crops at Strongsville will bear the same proportion to the first-year crops as that found at Wooster.

DIAGRAM V. ARRANGEMENT OF PLOTS IN 3-YEAR ROTATION OF POTATOES, WHEAT AND CLOVER, SOUTH FARM, CENTRAL STATION.

Plots one-tenth acre.

North.



conditions, and the hay crops there have thus far been plowed under in order to bring the land into better physical condition. The increase from the fertilizers in this experiment is given in Tables VIII and IX. From these tables it will be observed that the increase at Strongsville is generally larger than that at Wooster, but the variations, due to differences in fertilizing, follow the same general course, indicating that the general needs of the two soils are similar.

In Diagram VII the results of the two tests are consolidated, and the value of the increase is calculated as in Diagram IV, potatoes being

DIAGRAM VI. ARRANGEMENT OF PLOTS IN 3-YEAR ROTATION OF POTATOES, WHEAT AND CLOVER AT NORTHEASTERN SUBSTATION.

Plots one-twentieth acre.

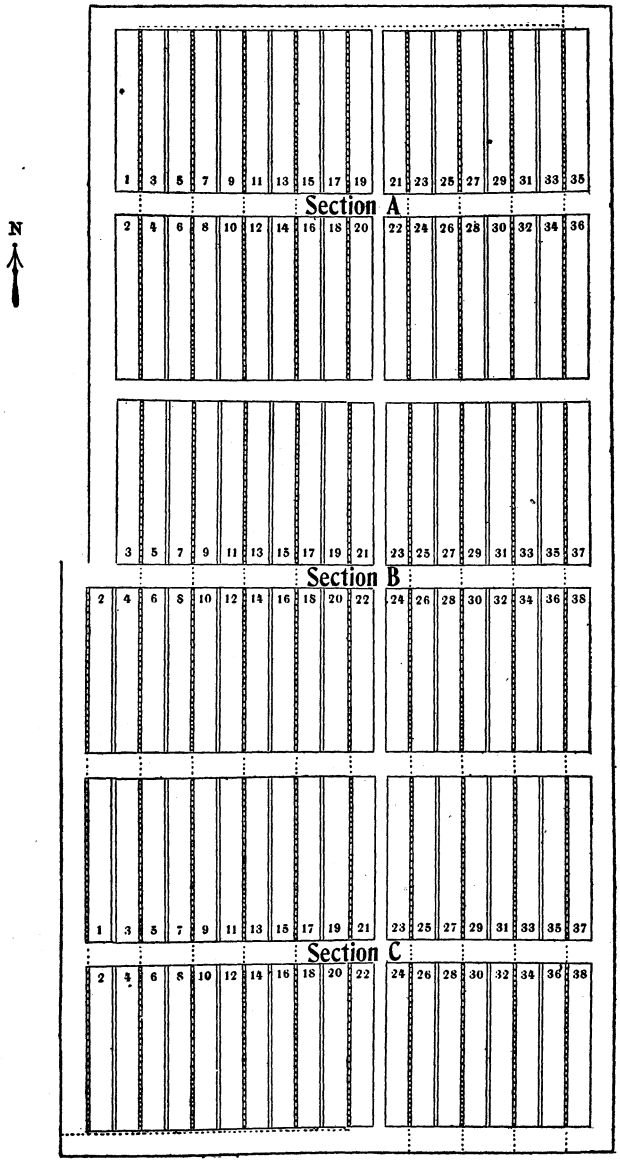


TABLE VII. PLAN OF FERTILIZING IN 3-YEAR ROTATION.

Fertilizers in pounds per acre.

Plot	Fertilizing materials per acre							Total fertilizers in 3 years	Total fertilizing constituents per acre			Cost of fertiliz'rs per acre
	On Potatoes			On Wheat								
	Superphosphate	Muriate of potash	Nitrate of soda	Superphosphate	Muriate of potash	Dried bl'd	Nitrate of soda		Phosphor'c acid	Potash	Nitrogen	
1	.....	.....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....
2	160	.....	.....	160	.....	....	.....	320	50	.....	.....	$2 40
3	.....	100	.....	.....	100	....	.....	200	.....	100	.....	5 00
4	.....	.....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....
5	.....	.....	80	.....	.....	40	120	240	.....	.....	38	6 00
6	160	.....	80	160	.....	40	120	560	50	.....	38	8 40
7	.....	.....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....
8	160	100	.....	160	100	....	.....	520	50	100	.....	7 40
9	.....	100	80	.....	100	40	120	440	.....	100	38	11 00
10	.....	.....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....
11	160	100	80	160	100	40	120	760	50	100	38	13 40
12	160	100	160	160	100	40	200	920	50	100	62	17 30
13	.....	.....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....
14	320	200	160	160	100	40	120	1,100	75	150	50	19 10
15	480	300	320	.....	.....	....	.....	1,100	75	150	50	19 10
16	.....	.....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....
17	.....	.....	.....	A	.....	....	.....	.....	.....	.....	.....	2 00
18	.....	.....	.....	B	.....	....	.....	.....	.....	.....	.....	4 00
19	.....	.....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....
20	80	85	C	D	70	....	.....	1,735	50	100	38	.....
21	120	95	E	110	90	....	F	1,165	50	100	38	.....
22	.....	.....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....
23	150	100	G	140	100	....	H	790	50	100	38	.....
24	160	100	I	160	100	....	K	700	50	100	38	.....
25	.....	.....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....
26	L	100	55	L	100	....	135	610	50	100	38	.....
27	M	100	80	M	100	40	120	760	50	100	38	.....
28	.....	.....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....
29	N	100	80	N	100	40	120	700	50	100	38	.....
30	B	.....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....
31	.....	.....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....
32	.....	.....	.....	O	.....	....	.....	.....	.....	.....	.....	.....
33	P	.....	.....	P	.....	....	.....	420	50	10	12	3 75
34	.....	.....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....
35	160	50	80	160	50	40	120	580	50	50	38	10 90
36	160	25	80	160	25	40	120	530	50	25	38	9 65
37	.....	.....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....
38	.....	.....	.....	.....	.....	....	.....	.....	.....	.....	.....	.....

Explanation: Superphosphate as dissolved bone black previous to 1897; as acid phosphate beginning with the spring of 1897.

A. Barnyard manure, 4 tons.
B. Barnyard manure, 8 tons.
C. Wheat bran, 500 pounds.
D. Wheat bran, 1,000 pounds.
E. Linseed oil meal, 250 pounds.
F. Linseed oil meal, 500 pounds.
G. Dried blood, 100 pounds.
H. Dried blood, 200 pounds.
I. Sulphate ammonia, 60 pounds.
K. Sulphate ammonia, 120 pounds.
Plots 35 to 38 at Strongsville only.
L. Bone meal, 110 pounds.
M. Acid phosphate, 170 pounds, 1894–96, dissolved bone black, 140 pounds, 1897 and 1898, 160 pounds, 1899.
N. Basic slag, 130 pounds.
O. Barnyard manure, 16 tons, beginning fall of 1896.
P. Acid phosphate, 100 pounds, tankage, 100 pounds, muriate of potash, 10 pounds, beginning 1896.

TABLE VIII. INCREASE FROM FERTILIZERS IN 3-YEAR ROTATION OF POTATOES, WHEAT AND CLOVER AT CENTRAL STATION, WOOSTER.

Plot	Total fertilizers applied during one rotation, in pounds per acre	Average increase in pounds per acre			
		Potatoes, 6 crops	Wheat, 5 crops		Hay, 4 crops
			Grain	Straw	
2	Superphosphate, 320	1116	224	334	161
3	Muriate of potash, 200	526	129	28	—61
5	Nitrate of soda, 200; dried blood, 40	405	138	370	198
6	Superphosphate, 320; nitrate of soda, 200; dried blood, 40	1792	455	748	398
8	Superphosphate, 320; muriate of potash, 200	1537	446	509	222
9	Muriate of potash, 200; nitrate of soda, 200; dried blood, 40	977	394	457	402
11	Superphosphate, 320; muriate of potash, 200; nitrate of soda, 200; dried blood, 40	1214	524	779	132
12	Superphosphate, 320; muriate of potash, 200; nitrate of soda, 360; dried blood, 40	1772	599	995	478
14	Superphosphate, 480; muriate of potash, 300; nitrate of soda, 280; dried blood, 40	367	661	1017	440
15	Superphosphate, 480; muriate of potash, 300; nitrate of soda, 280; dried blood, 40	2406	553	762	550
17	Barnyard manure, 4 tons, on wheat only	605	173	280	485
18	Barnyard manure, 8 tons, on wheat only	811	262	395	949
20	Superphosphate, 80; muriate of potash, 155; wheat bran, 1,500	2027	308	482	745
21	Superphosphate, 230; muriate of potash, 185; linseed oil-meal, 750	1615	506	702	405
23	Superphosphate, 290; muriate of potash, 200; dried blood, 300	1899	529	834	75
24	Superphosphate, 320; muriate of potash, 200; sulphate of ammonia, 180	1558	539	809	167
26	Raw bone meal, 220; muriate of potash, 200; nitrate of soda, 190	1063	592	1033	208
27	Acid phosphate, 320; muriate of potash, 200; nitrate of soda, 200; dried blood, 40	1313	597	932	192
29	Slag phosphate, 260; muriate of potash, 200; nitrate of soda, 200; dried blood, 40	1159	641	1059	915
30	Barnyard manure, 8 tons, on potatoes only	2186	252	315	706
32	Barnyard manure, 16 tons, on wheat only	[2]1510	513	811	926
33	Acid phosphate, 200; muriate of potash, 20; 7 and 30 tankage, 200	[3]578	595	911	328

[1] 5 crops. [2] 2 crops. [3] 4 crops.

TABLE IX. INCREASE FROM FERTILIZERS IN 3-YEAR ROTATION OF POTATOES, WHEAT AND CLOVER AT NORTHEASTERN SUBSTATION, STRONGSVILLE.

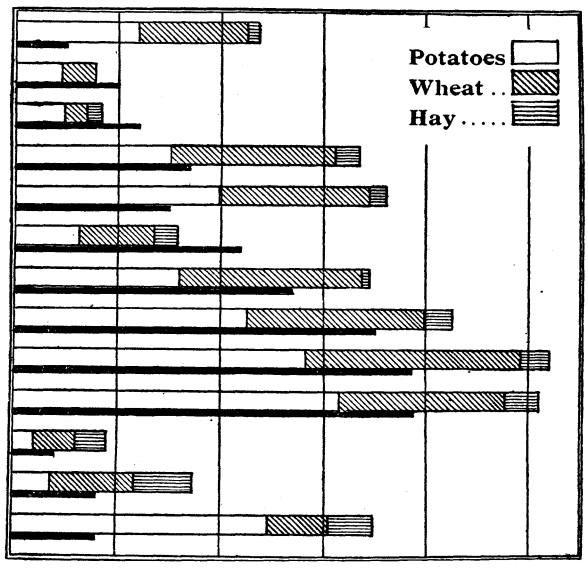
Plot	Total fertilizers applied during one rotation, in pounds per acre.	Average increase in pounds per acre		
		Potatoes, 4 crops	Wheat, 3 crops	
			Grain	Straw
2	Superphosphate, 320	1251	662	1254
3	Muriate of potash, 200	152	177	232
5	Nitrate of soda, 200; dried blood, 40	422	19	139
6	Superphosphate, 320; nitrate of soda, 200; dried blood, 40	[1]901	944	1430
8	Superphosphate, 320; muriate of potash, 200	1805	888	1280
9	Muriate of potash, 200; nitrate of soda, 200; dried blood, 40	[1]87	122	198
11	Superphosphate, 320; muriate of potash, 200; nitrate of soda, 200; dried blood, 40	1532	1003	1573
12	Superphosphate, 320; muriate of potash, 200; nitrate of soda, 360; dried blood, 40	2051	1041	1665
14	Superphosphate, 480; muriate of potash, 300; nitrate of soda, 280; dried blood, 40	2608	1137	1747
15	Superphosphate, 480; muriate of potash, 300; nitrate of soda, 280; dried blood 40	2941	821	1230
17	Barnyard manure, 4 tons, on wheat only	[2]*101	188	128
18	Barnyard manure, 8 tons, on wheat only	[2]424	502	728
20	Superphosphate, 80; muriate of potash, 155; wheat bran, 1,500	1241	271	281
21	Superphosphate, 230; muriate of potash, 185; linseed oil-meal, 750	1778	868	1156
23	Superphosphate, 290; muriate of potash 200; dried blood, 300	1338	813	1136
24	Superphosphate, 320; muriate of potash, 200; sulphate of ammonia, 180	1379	718	1164
26	Raw bone meal, 220; muriate of potash, 200; nitrate of soda, 190	1367	1052	1629
27	Acid phosphate, 320; muriate of potash, 200; nitrate of soda, 200; dried blood, 40	1996	774	1193
29	Slag phosphate, 260; muriate of potash, 200; nitrate of soda, 200; dried blood, 40	1972	1097	1611
30	Barnyard manure, 8 tons, on potatoes only	1898	185	393
32	Barnyard manure, 16 tons, on wheat only	359	916	1291

[1] 3 crops. [2] 2 crops. * Decrease.

DIAGRAM VII. FERTILIZERS APPLIED PER ACRE ON CROPS GROWN IN 3-YEAR ROTATION AND VALUE OF INCREASE PER ACRE.

Average of 8 rotations.

Plot No.	Fertilizers applied in three years: Superphosphate	Muriate of Potash	Nitrate of Soda*
	Pounds	*Pounds*	*Pounds*
2	320	...	...
3	...	200	...
5	...	...	240
6	320	...	240
8	320	200	...
9	...	200	240
11	320	200	240
12	320	200	400
14	480	300	320
15	480	300	320
17	Barnyard manure, 4 tons, on wheat		
18	Barnyard manure, 8 tons on wheat		
30	Barnyard manure, 8 tons, on potatoes		



*Nitrate of soda and dried blood.

valued at 60 cents per cental, or 36 cents per bushel, and wheat, straw and hay at the prices previously given.

Following the lines of this diagram we see that the potato and wheat crops have both been largely increased by the fertilizers, and that in this test, as in the cereal rotation, phosphoric acid has been the dominant factor in producing this increase. It will be observed that usually more than half the total increase is found in the potato crop, even at the low price at which the potatoes are valued; that there has been a profit in the use of fertilizers wherever phosphoric acid was a constituent of the fertilizer, and a loss wherever phosphoric acid was omitted.

The lines showing the larger applications of fertilizers indicate a larger total, but a smaller relative profit than when the fertilizers are used in smaller quantity; but if potatoes were valued at a higher price it would alter these proportions in favor of the more liberal use of fertilizers. We have found, in fact, that when potatoes are worth $1.00 per cental, or 60 cents per bushel, a not unusual price, the net profit on Plots 14 and 15 exceeds that on any other plot in the series, except that on Plot 8.

In the case of the potato crop the increase is less regular than that of the wheat crop in this rotation, or of the cereal crops in the longer rotation previously considered. The tables show that there has been a marked increase in the yield of potatoes wherever phosphoric acid has been applied in the fertilizer, and an insignificant increase where this constituent was omitted. The increase on Plot 2, receiving superphosphate only, compared with Plots 6, 8 and 11, on which the superphosphate has been re-enforced with nitrogen or potash, one or both, indicates that potash has produced a small increase in yield over that given by phosphoric acid alone, but leaves us in doubt whether there has been anything gained, in the soils under test, by adding nitrogen to a fertilizer for potatoes grown on a clover sod. At the Central Station the clover crops in this experiment have made good yields, with very small and irregular increase from the fertilizers. Only the first crop has been weighed each year. When the seed crop has been saved it has not been harvested separately. The clover crops at the Sub-station have been smaller, sometimes quite weedy, and, as previously stated, they have thus far been plowed under.

In the case of the wheat following the potatoes, the tables show that phosphoric acid has been an important factor in producing increase in yield, yet both potash and nitrogen have added materially to this increase, as shown below:

TABLE X. INCREASE OF WHEAT FOLLOWING POTATOES

Plot	Fertilizers	Increase, in pounds per acre			
		Wooster		Strongsville	
		Grain	Straw	Grain	Straw
2	Phosphoric acid alone	224	334	662	1254
8	Phosphoric acid and potash	446	509	888	1280
6	Phosphoric acid and nitrogen	455	748	944	1430
11	Phosphoric acid, potash and nitrogen	524	779	1003	1573
12	Phosphoric acid, potash and more nitrogen	599	995	1041	1665

Apparently, the surplus nitrogen accumulated in the soil by the clover crop is chiefly consumed by the potato crop following.

It will be observed that in this experiment Plots 14 and 15 receive the same total quantity of each of the fertilizing constituents, but on Plot 14 the dressing is divided between the potatoes and the wheat, while on Plot 15 it is all given to the wheat. The relative effect of the two modes of application is well brought out by the diagram.

FERTILIZERS ON CROPS GROWN IN CONTINUOUS CULTURE.

Experiments in the use of fertilizers and manures on wheat grown continuously on the same land were begun on the farm belonging to the Ohio State University, at Columbus, Franklin county, soon after the first organization of the Station, but the land then available proved to be unsuited to the work, and on the reorganization of the Station, under the Hatch act, a new location on the same farm was selected and prepared for the work by thorough underdraining. At the same time the scope of the test was extended to include corn and oats as well as wheat. The test was conducted under the immediate superintendence of the Agriculturist of the Station until the removal of the Station to Wooster, in 1892, since which time it has been carried on through coöperation between the Station and the Farm Department of the University, of which Prof. Thos. F. Hunt, Dean of the College of Agriculture, has been in charge.

The soil devoted to this test is of combined glacial and fluvial origin. The land lies on the east bank of the Olentangy river, at an elevation of about 20 feet above the present flood plain. The portion nearest the river lies upon a bed of gravel, which is found at a depth of two to five feet, and which gives a pervious subsoil; this portion is occupied by the corn and oats; the wheat, however, grows upon a soil 12 to 18 inches in depth, overlying a thick sheet of bowlder clay, almost impervious to water. The original forest growth was chiefly Beech and Elm on this portion, while Black Walnut (*Juglans nigra* L.) was found on the portion nearer the river. The subsoil in this test has been explored by a line of wells, four or five feet deep, dug along the east and west roadway separating the sections. Between the corn and oats these wells ended in dry gravel, but along the wheat they terminated in bowlder clay and immediately filled with water to the level of the tile drains. The line of division apparently lies under the first plots of the wheat.

The mechanical and chemical analyses, given on pp. 6 and 7, are of the soil of that portion of the tract on which wheat is grown, and show a soil rich in the mineral elements of fertility. Under-drainage, however, was essential to successful agriculture on this part of the tract, while it was needed on the remainder to equalize the moisture conditions, the gravel being in some places too far from the surface to give sufficient natural drainage.

Table XI gives the plan of fertilizing followed in this experiment, each crop receiving the same treatment, except that in the case of wheat one-fourth of the total nitrogen has been given as dried blood, applied in the fall with the seed, and three-fourths as nitrate of soda, sown broadcast in April, except on Plot 15, the sulphate of ammonia being all given in the fall.

Simultaneously with the beginning of this experiment, in 1888, the Agriculturist of the Station, Mr. J. F. Hickman, began an experiment in the continuous culture of corn on his farm near East Liverpool, Colum-

DIAGRAM VIII. ARRANGEMENT OF PLOTS IN EXPERIMENTS IN CONTINUOUS CULTURE AT COLUMBUS.

Plots one-tenth acre.

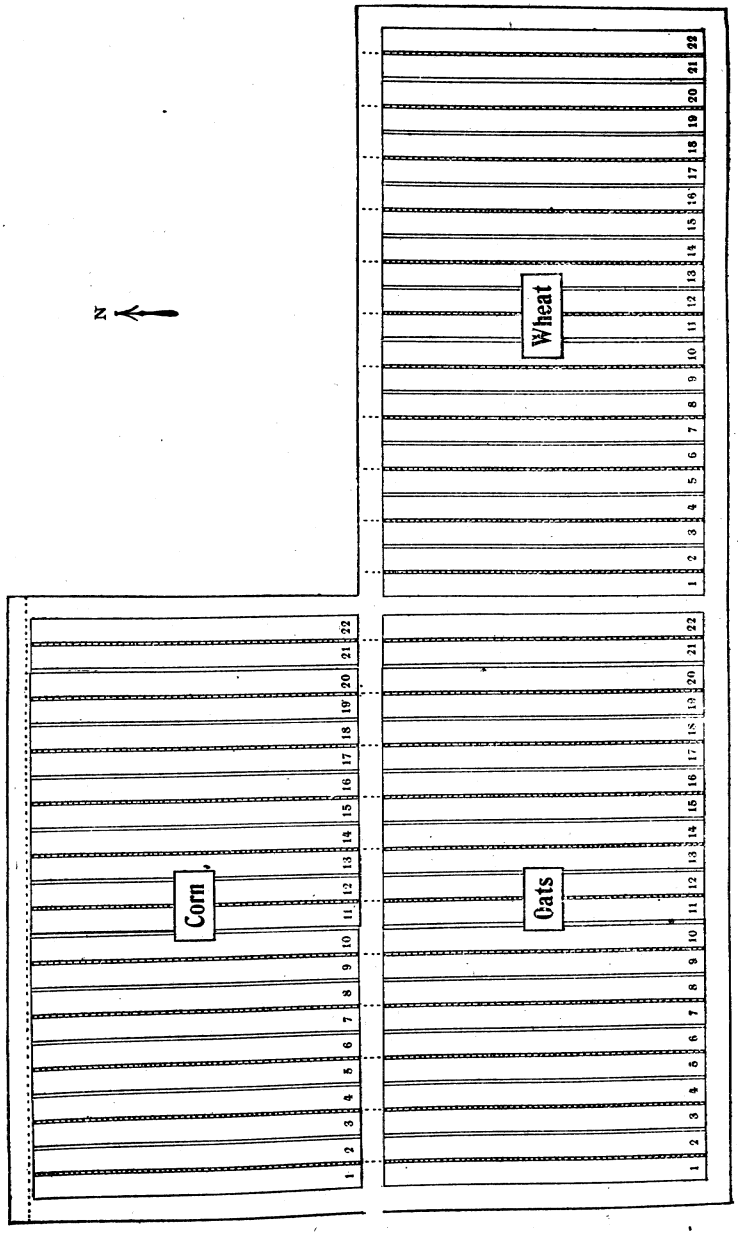


TABLE XI. PLAN OF FERTILIZING ON CROPS GROWN IN CONTINUOUS CULTURE AT COLUMBUS.

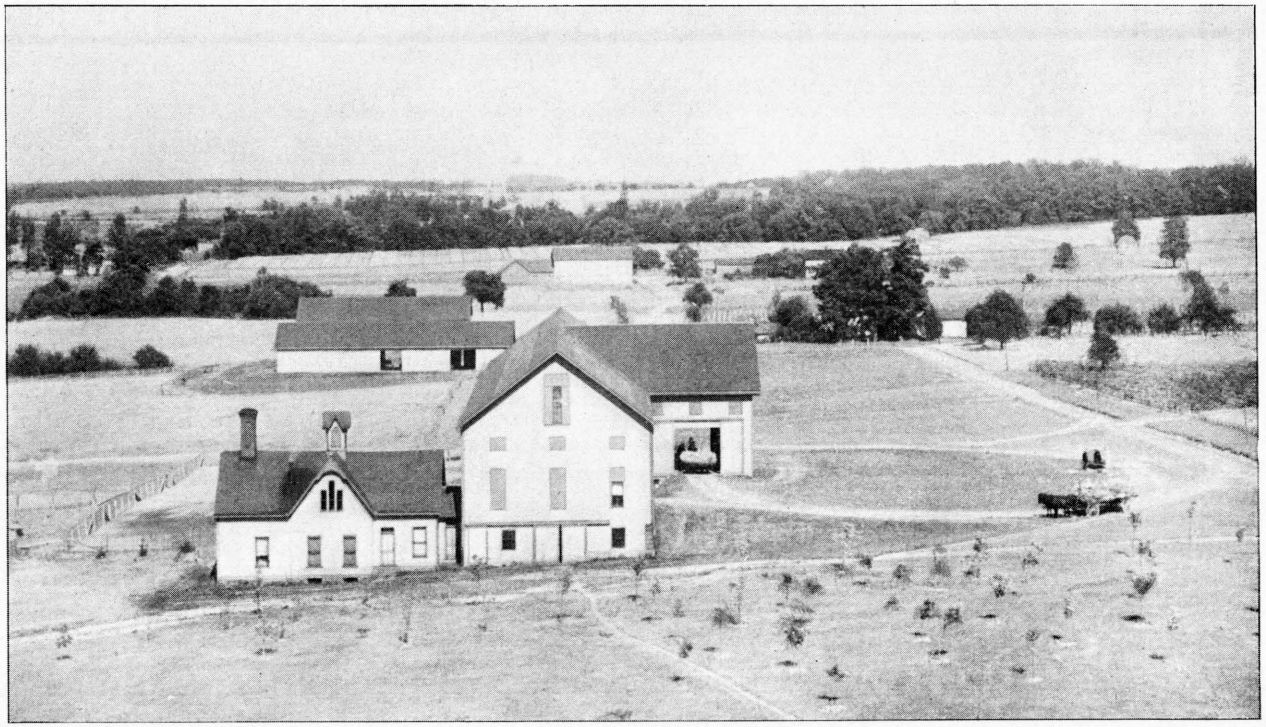
Plot	Fertilizing materials in pounds per acre
1	None.
2	Superphosphate, 320.
3	Muriate of potash, 80.
4	None.
5	Nitrate of soda, *160.
6	Superphosphate, 320; nitrate of soda, *160.
7	None.
8	Superphosphate, 320; muriate of potash, 80.
9	Muriate of potash, 80; nitrate of soda, *160.
10	None.
11	Superphosphate, 320; muriate of potash, 80; nitrate of soda, *160.
12	Superphosphate, 320; muriate of potash, 80; nitrate of soda, *320.
13	None.
14	Superphosphate, 320; muriate of potash, 80; nitrate of soda, *480.
15	Superphosphate, 320; muriate of potash, 80; sulphate of ammonia, 120.
16	None.
17	Acid phosphate, 320; muriate of potash, 80; nitrate of soda, *160.
18	Slag phosphate, 320; muriate of potash, 80; nitrate of soda, *160.
19	None.
20	Barnyard manure, 8 tons.
21	Linseed oil-meal, 1000 lbs.
22	None.

* For wheat, 40 lbs. dried blood, and the remainder nitrate of soda.

TABLE XII. PLAN OF FERTILIZING CORN, GROWN IN CONTINUOUS CULTURE AT EAST LIVERPOOL.

Plot	Fertilizing materials, in pounds, per acre, since 1894. (Half these quantities previously.)
1	None.
2	Superphosphate, 640.
3	Muriate of potash, 160.
4	None.
5	Nitrate of soda, 320.
6	Superphosphate, 640; nitrate of soda, 320.
7	None.
8	Superphosphate, 640; muriate of potash, 160.
9	Muriate of potash, 160; nitrate of soda, 320.
10	None.
11	Superphosphate, 640; muriate of potash, 160; nitrate of soda, 320.
12	Barnyard manure, 16 tons.
13	None.
14	Land plaster, 800.

PLATE VII.



Looking east from the tower of the main building in harvest time. Section C of the 5-year rotation, fertilizer tests, in the distance.

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TABLE XIII. PLAN OF FERTILIZING CROPS GROWN IN CONTINUOUS CULTURE AT WOOSTER.

Fertilizing materials in pounds per acre.

Plot	On Corn			On Oats			On Wheat			
	Super-phos-phate	Muri-ate of potash	Nitrate of soda	Super-phos-phate	Muri-ate of potash	Nitrate of soda	Super-phos-phate	Muri-ate of potash	Dried blood	Nitrate of soda
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	160	100	160	160	100	160	160	100	40	120
3	60	30	160	55	50	160	45	30	40	120
4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
5	A	.....	.....	A	.....	.....	A	.....	.....	.....
6	B	.....	.....	B	.....	.....	B	.....	.....	.....
7	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
8	160	100	320	160	100	320	160	100	40	280
9	120	60	320	110	100	320	90	60	40	280
10	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....

A Barnyard manure, 5,000 lbs. B Barnyard manure, 10,000 lbs.

biana county, which he has continued at his personal expense up to this date. The soil here under test is a thin sheet of clay, not more than twelve to eighteen inches in thickness, lying upon argillaceous shales of the coal measures. These shales have weathered at the surface into the overlying soil, and their loose stratification gives even excessive drainage. It is a soil in which the necessity for maintaining the humus supply has been demonstrated by practical experience. Where it has lain several years in grass it will produce one or two good crops of grain, after which it must be seeded to grass again. The plan of fertilizing in this test is given in Table XII.

Upon the removal of the Experiment Station from Columbus to Wooster an experiment was begun in the continuous culture of the cereals, following the plan of fertilizing given in Table XIII, the object in this test being more particularly to study the ability of the different crops to secure plant food and the relative availability of the chief fertilizing constituents as found in ordinary commercial fertilizers and in barnyard manure. The cropping in this test began in 1894.

In these experiments, therefore, corn has been grown continuously for 12 years at Columbus and East Liverpool, and for 5 years at Wooster (the corn crops of 1899 not being harvested in season to be included here). Oats has been grown 10 years at Columbus and 6 years at Wooster, and wheat has been grown 11 years at Columbus and 6 years at Wooster.

FERTILIZERS ON CORN GROWN IN CONTINUOUS CULTURE.

Table XIV shows the average yield and increase of corn at Columbus for the 11 years, 1888-98.

From this table it is seen at a glance that there has been a falling off in the unfertilized plots, amounting to nearly one-half the grain and more than one-half the stover, over the later period as compared with the earlier one. It also appears that the fertilizers have not been able to materially check this downward tendency, the average increase on the 14 fertilized plots being 237 pounds of ears and 567 pounds of stover for the first period, against 251 pounds of ears and 378 pounds of stover for the second period. Even the annual application of 8 tons of barnyard manure has not been sufficient to maintain the yield, the relative loss on the manured plot being in fact somewhat greater than on some of the fertilized plots.

TABLE XIV. FERTILIZERS ON CORN GROWN CONTINUOUSLY AT COLUMBUS.

Average yield and increase or decrease (—) in pounds per acre.

Plot	5 years, 1888–1892				6 years, 1893–1898				11 years, 1888–1898			
	Yield		Increase		Yield		Increase		Yield		Increase	
	Ears	Stover	Ears	St'v'r	Ears	Stover	Ears	St'v'r	Ears	Stover	Ears	Sto.
1	4,544	4,114	.....	.....	2,225	1,602	.....	.....	3,280	2,744	.....	....
2	4,479	3,779	–118	–286	2,418	1,740	166	89	3,355	2,668	–17	–81
3	4,579	4,438	–69	423	2,827	2,061	347	360	3,623	3,142	160	389
4	4,700	3,966	.....	.....	2,607	1,750	.....	.....	3,558	2,758	.....	....
5	4,935	4,837	311	841	2,906	2,100	305	338	3,829	3,344	309	566
6	5,030	4,643	484	617	2,778	2,102	184	329	3,802	3,257	320	460
7	4,470	4,056	.....	.....	2,588	1,785	.....	.....	3,444	2,817	.....	....
8	4,617	4,371	116	295	2,884	2,328	335	560	3,672	3,256	235	439
9	5,016	4,835	483	738	2,877	2,059	368	309	3,853	3,321	420	504
10	4,564	4,117	.....	.....	2,470	1,733	.....	.....	3,422	2,816	.....	....
11	4,939	4,507	336	362	2,936	2,327	474	603	3,846	3,318	411	494
12	5,050	4,578	409	406	2,886	2,151	434	435	3,870	3,254	422	422
13	4,680	4,200	.....	.....	2,446	1,707	.....	.....	3,870	3,254	422	422
14	4,886	4,666	368	732	2,608	2,135	250	452	3,643	3,286	303	580
15	4,568	4,718	213	[1]935	2 776	2,246	503	587	3,591	3,235	371	[2]726
16	4,193	3,402	.....	.....	2,187	1,635	.....	.....	3,099	2,438	.....	....
17	4,725	4,471	571	978	2,626	2,002	456	380	3,580	3,125	508	652
18	4,705	4.277	591	692	2,608	1,991	455	381	3,562	3,030	517	523
19	4,075	3,676	.....	.....	2,136	1,597	.....	.....	3,018	2,542	.....	....
20	4,738	4,000	433	277	2,561	1,861	388	234	3,550	2,833	408	254
21	5,151	4,699	617	930	2,563	1,780	354	124	3,739	3,107	472	490
22	4,764	3,816	.....	.....	2,246	1,686	.....	.....	3,391	2,654	.....	....
*	4,499	3,918	.....	.....	2,363	1,687	.....	.....	3,334	2,701	.....	....

[1] 4 years.
[2] 10 years.
* Average unfertilized yield.

TABLE XV. FERTILIZERS ON CORN GROWN CONTINUOUSLY AT EAST LIVERPOOL.

Average yield and increase in pounds per acre.

Plot	5 years, 1888–1892				6 years, 1893–1898				11 years, 1888–1898			
	Yield		Increase		Yield		Increase		Yield		Increase	
	Ears	Stover	Ears	St'v'r	Ears	Stover	Ears	St'v'r	Ears	Stover	Ears	S'v'r
1	2,053	2,737	.....	.....	813	1,302	.....	.....	1,377	1,951	.....	....
2	2,081	2,850	-106	87	780	1,181	-42	-132	1,372	1,940	-71	-32
3	2,246	3,078	-76	289	890	1,276	58	-47	1,506	2,095	-3	107
4	2,456	2,815	.....	.....	841	1,334	.....	.....	1,575	2,007	.....	....
5	3,139	3,363	498	500	1,002	1,392	138	—1	1,972	2,288	300	227
6	3,412	3,468	586	557	1,252	1,744	364	293	2,234	2,528	466	413
7	3,011	2,959	.....	.....	911	1,510	.....	.....	1,865	2,169	.....	....
8	2,631	3,459	-347	464	954	1,326	17	-225	1,716	2,295	-148	87
9	3,566	3,740	621	709	1,270	1,757	308	164	2,313	2,659	450	412
10	2,912	3,067	.....	.....	988	1,634	.....	.....	1,862	2,286	.....	....
11	3,107	3,565	278	514	1,641	2,261	666	632	2,308	2,854	490	578
12	3,044	3,559	296	524	1,633	2,333	672	710	2,274	2,890	501	625
13	2,665	3,019	.....	.....	948	1,618	.....	.....	1,728	2,255	.....	....
14	2,512	2,997	-153	-22	902	1,382	-46	-236	1,633	2,115	-95	-140
*	2,619	2,919	.....	.....	900	1,480	.....	.....	1,681	2,134	.....	....

*Average unfertilized yield.

TABLE XVI. YIELD OF CORN GROWN IN CONTINUOUS CULTURE COMPARED WITH AVERAGE COUNTY YIELD.

Yield of car-corn in bushels per acre.

Year	Columbus			Franklin County	East Liverpool			Columbiana County
	Unfertilized	Plot 11	Plot 20		Unfertilized	Plot 11	Plot 12	
1888	81.5	75.8	79.5	43.2	52.4	71.1	58.5	38.0
1889	58.3	67.4	62.8	29.4	57.7	64.7	73.3	35.8
1890	43.6	48.1	44.9	31.5	22.0	24.3	29.7	27.4
1891	57.3	69.5	62.7	38.3	27.7	30.6	28.0	33.6
1892	65.4	76.0	70.3	40.7	19.1	23.7	21.7	32.1
5– year average...	61.2	67.4	64.0	36.6	35.8	42.9	42.2	33.4
1893	38.6	41.2	39.8	35.0	7.6	9.3	6.9	30.3
1894	42.7	51.5	40.6	37.0	.....	.....	.....	22.6
1895	21.3	19.1	30.5	36.0	28.2	51.5	54.7	40.0
1896	46.8	56.4	47.9	41.9	30.2	43.5	43.0	39.9
1897	34.2	43.0	44.4	37.1	.....	.....	.....	30.3
1898	18.9	29.0	27.7	37.0	11.1	36.1	35.4	42.4
6–year average ...	33.7	40.0	38.5	37.3	12.8	23.4	23.3	34.3

Turning to the test at East Liverpool, as exhibited in Table XV, we find a very similar condition of affairs. In this test there was a rapid decline in yield from the beginning, and the crop of 1894 was so complete a failure that no attempt was made to harvest the grain separately. The quantities of fertilizers and manure were then doubled for 1895 and succeeding seasons, and yet these heavy applications were not able to restore the yield to that of the first two years of the test. In fact, there was a second failure of crop in 1897, when no grain was harvested, the total yield for this season amounting to less than 400 pounds per acre on plots 11 and 12.

Table XVI gives the actual yields, in these two tests, of the average of the unfertilized plots, of Plot 11, receiving the complete fertilizer, and of the manured plot, over the two periods under consideration, as compared with the average yield for the same periods of the two counties in which the tests are located, as reported by the township assessors:

It will be observed that in both tests the unfertilized yield is greater than the average yield of the county over the first period, but smaller over the second; that the yield of the fertilized and manured plots is conspicuously greater than the average yield of the county over the first period, but is only slightly greater at Columbus and very much smaller at East Liverpool over the second. In both cases the county yields are slightly greater over the second period than over the first.

Farmers on upland soils have long since learned that corn grows best on a decaying sod, and it is the general custom, in such regions, to practice a more or less systematic rotation, in which corn follows grass or clover. In the rich bottom lands of the river valleys, however, this necessity for rotation has not been so strongly enforced, and in these regions of the state there are many fields which are planted in corn continuously, year after year.

The soils of Columbiana county are almost exclusively upland, its few valleys being quite narrow, and the general practice is to turn under an old, blue-grass sod, grow one or two crops of corn on it, and then seed down to grass again with wheat. This practice is, of course, not universally followed; there are many careless farmers who do not heed the lessons of experience and whose meager crops reduce the general average. Comparing the yields obtained in the test at East Liverpool with those of Columbiana county, we see that for the first two seasons the unfertilized yield in this test considerably exceeds the average yield of the county, but with the third crop it falls behind and loses ground constantly from that time forth. The fertilized and manured plots make a little better record, but even the large dressing of 16 tons of barnyard manure per acre is only temporarily able to bring up the yield to that of the county.

Franklin county is very different in topography and character of soil from Columbiana. The entire county is covered with the drift of the

glacial epoch, giving a soil rich in all the mineral elements of fertility, while it is traversed by five considerable streams, three of which cross the entire county from north to south, and all of which, with their numerous smaller tributaries, have wide flood plains along a considerable part of their course. Between some of these valleys lie broad "second bottoms" of gravelly soil—the flood plains of the ancient glacial rivers—which are quite as productive, when properly handled, as the bottoms themselves, while at a little higher elevation are beds of bowlder clay, rich in the mineral constituents of fertility (see analysis, p. 6), but requiring underdrainage to make their stores available.

The potential corn production of this entire county, we believe, is only fairly represented by the yields in this test over the first period, which, it will be seen, are far above the average yields of the county; the possible yields of the latter being not attained because of continuous cropping on the bottom lands, and lack of drainage on the uplands.

It will be observed that it is not until the eighth year of continuous cropping, in the test under consideration, that the yield falls below that of the county, while for the first two seasons it is almost double that of the county.

It seems apparent, from this test, that the present need of this soil for corn production is not so much the addition of purchased fertility, as the systematic practice of drainage and crop rotation, including the culture of nitrogen gathering crops.

The natural conditions of Franklin county are, in greater or less degree, typical of a vast region occupying the western and southwestern portions of the state; the region including the valleys of the Miamis, the Scioto, and a large portion of the Muskingum, with the great drift plains lying between.

The experiment in the continuous culture of corn at Wooster differs from those previously considered in having been commenced on a soil already depleted of fertility. The land had been in wheat in 1892—the last year of a long term of tenant farming. There was, therefore, no such store of accumulated fertility to begin upon as in the case of the clover sod at Columbus, or the old, blue-grass sod at East Liverpool. In the spring of 1893 it was underdrained and planted to corn, the work of draining delaying the corn planting to a late date and the crop was harvested simply as fodder.

The average yield of the five crops, harvested 1894 to 1898, is given in Table XVII, and in Table XVIII is given a comparison of the yields in this test and also in the rotative cropping with those in Wayne county over the same period. From this table it appears that the unfertilized yield on this thin soil is far below the average yield of the county, while the yield on the fertilized and manured plots is considerably above that of the county. In comparing the plans of fertilizing in the different tests it will be seen that Plots 2 and 8, in this test, receive the same quantity of

TABLE XVII. FERTILIZERS ON CORN GROWN CONTINUOUSLY AT WOOSTER.

Fertilizers, yield and increase in pounds per acre.

Plot	Fertilizers per acre annually			5-year average yield and increase			
				Yield		Increase	
	Super-phos-phate	Muriate of potash	Nitrate of soda	Ear-corn	Stover	Ear-corn	Stover
1				2,043	1,449		
2	160	100	160	3,123	2,076	1,087	631
3	60	30	160	2,720	1,770	692	330
4				2,020	1,436		
5	*			2,551	1,670	608	278
6	**			3,019	1,938	1,154	590
7				1,787	1,304		
8	160	100	320	3,110	2,008	1,418	749
9	120	60	320	2,993	1,870	1,397	655
10				1,501	1,170		
Average unfertilized yield				1,838	1,340		

* Barnyard manure, 5,000 lbs. per acre
** Barnyard manure, 10,000 lbs. per acre.

TABLE XVIII. YIELD OF CORN GROWN AT THE EXPERIMENT STATION COMPARED WITH AVERAGE COUNTY YIELD.

Yield per acre in bushels of 70 pounds of ears.

Year	Yield at Experiment Station, Wooster						Yield of Wayne county
	Continuous culture			Rotation			
	Average unfertil-ized	Plot 2 complete fertilizer	Plot 6 barnyard manure	Average unfertil-ized	Plot 11 complete fertilizer	Plot 18 barnyard manure	
1894	16.5	24.8	23.1	18.6	20.5	17.8	24.9
1895	28.3	38.2	47.5	35.4	42.1	*37.2	37.9
1896	48.8	73.2	68.8	52.0	68.6	58.7	40.5
1897	10.0	29.6	25.6	25.9	33.9	46.0	37.6
1898	28.0	57.1	50.6	27.6	41.4	40.4	42.0
Average	26.3	44.6	43.1	31.9	41.3	40.0	36.6

* Plot 20.

nitrogen, with half the phosphoric acid and a little more potash than is given to Plots 11 and 12, in the test at Columbus; and Plot 6, in the Wooster test, receives 6 tons of manure, while Plot 20 at Columbus receives 8 tons. It will be observed that the unfertilized yield in this test is considerably smaller than that of the Columbus test over the last six years, while the yield on the fertilized and manured plots is considerably larger. But the yield for Wayne county in general is only seven-tenths of a bushel less than that for Franklin county; it would appear, therefore, that the Wayne county soil has responded more effectively to both fertilizer and manure than that at Columbus.

FERTILIZERS ON OATS GROWN CONTINUOUSLY ON THE SAME LAND.

An experiment in the continuous culture of oats, with and without manure and fertilizers, was begun in 1889 on the farm belonging to the State University at Columbus, the land devoted to this test being of the same general character and previous history as that carrying the test in continuous corn culture just described. The land was underdrained in the spring of 1888, the work being completed in time for planting corn, but too late for oats, so a crop of millet was grown that season, without fertilizer, and the experiment with oats was begun the following spring. The plan of fertilizing is given in Table XI, the plots of the same number being continuous through oats and corn, as are the tile drains, which are laid under alternate dividing spaces (See Diagram VIII). The entire tract slopes gently to the North. The record in this test has unfortunately been broken in the case of several of the plots, so that a complete average of the yield for the entire period can only be given for Plots 4 to 16 inclusive. This is given in Table XIX, which includes also the average yield of the two 5-year periods, 1889-1893 and 1894-1898 inclusive.

From this table we see that nitrogen has apparently been the most effective of the three chief fertilizing constituents, when used separately, but that the effect is increased by the addition of phosphoric acid or potash. When these are used without nitrogen, however, their effect is very small. The largest average yield of grain in this test has been produced on Plot 12, receiving 320 pounds of nitrate of soda yearly; the total yield of grain and straw however, is slightly larger on Plot 14, receiving 480 pounds of nitrate of soda. This large application frequently caused the oats to lodge and thus much of the possible effect was lost.

It will be observed that no fertilized plot gives as large an average yield during the second period as during the first. The yield of grain on the manured plot is practically the same, but there is a considerable falling off in the yield of straw.

The experiment in the continuous culture of oats at Wooster was begun in 1894, on land adjoining that devoted to the similar experiment

TABLE XIX. FERTILIZERS ON OATS GROWN CONTINUOUSLY AT COLUMBUS.

Yield and increase in pounds per acre

Plot	5 years, 1889–1893				5 years, 1894–1898				10 years, 1889–1898			
	Yield		Increase		Yield		Increase		Yield		Increase	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Str'w
1	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....
2	.....	.....	.....	.....	.....	.....	.....	.....	[1]974	2182	21	248
3	.....	.....	.....	.....	.....	.....	.....	.....	[2]1078	2286	125	352
4	1043	2430	.....	.....	862	1438	.....	.....	953	1934	.....	.....
5	1189	2750	147	345	1004	1921	155	490	1097	2335	151	417
6	1227	2711	186	331	1152	2074	316	650	1189	2392	250	490
7	1040	2355	.....	.....	823	1417	.....	.....	932	1886	.....	.....
8	1140	2705	58	252	957	1583	111	178	1048	2144	84	215
9	1265	2855	142	304	1104	2068	235	676	1184	2461	188	490
10	1165	2649	.....	.....	892	1380	.....	.....	1028	2014	.....	.....
11	1365	2949	179	281	1112	2371	222	942	1239	2673	201	612
12	1363	3078	155	391	1229	2676	341	1197	1296	2877	249	794
13	1229	2706	.....	.....	886	1528	.....	.....	1057	2117	.....	.....
14	1304	2955	118	391	1186	2888	319	1389	1245	2922	219	890
15	1305	2867	162	444	1148	2362	301	891	1227	2619	331	668
16	1100	2281	.....	.....	828	1442	.....	.....	964	1861	.....	.....
17	.....	.....	.....	.....	.....	.....	.....	.....	[3]1193	2405	211	567
18	.....	.....	.....	.....	.....	.....	.....	.....	[3]1187	2362	201	508
19	.....	.....	.....	.....	.....	.....	.....	.....	[4]996	2149	.....	.....
20	1151	2673	91	289	[6]1149	2388	240	577	[5]1133	2546	157	417
21	.....	.....	.....	.....	.....	.....	.....	.....	[5]1073	2665	128	449
22	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....
—	1115	2484	143	342	858	1441	250	802	988	1993		

1 9 years, excluding 1893. 3 8 years, excluding 1893 and 1896. 5 9 years, excluding 1895.
2 9 years, excluding 1894. 4 8 years, excluding 1893 and 1895. 6 4 years, excludiug 1895.

TABLE XX. FERTILIZERS ON OATS GROWN CONTINUOUSLY AT WOOSTER.

Fertilizers, yield and increase in pounds per acre.

Plot	Fertilizers per acre annually			6-year average yield and increase			
	Super-phos-phate	Muriate of potash	Nitrate of soda	Yield		Increase	
				Grain	Straw	Grain	Straw
1	.....	.....	.....	845	852	.....	.....
2	160	100	160	1372	1701	507	795
3	55	50	160	1272	1465	387	505
4	.....	.....	.....	905	1014	.....	.....
5	*	.....	.....	992	1011	88	—19
6	**	.....	.....	1145	1300	242	252
7	.....	.....	.....	902	1065	.....	.....
8	160	100	320	1642	2183	729	1107
9	110	100	320	1572	2065	647	977
10	.....	.....	.....	936	1099	.....	.....
Average unfertilized yield.....				897	1007		

* Barnyard manure, 5,000 pounds per acre. ** Barnyard manure, 10,000 pounds per acre.

with corn. The average results for the six years, 1894-99, are given in Table XX.

Comparing the yields, as given in this table, with those obtained at Columbus, we see that with oats, as with corn, the unfertilized yields at Wooster are far below those at Columbus during the first five years of the experiment there, but approximate those of the second 5-year period. The ratio of straw to grain is much larger at Columbus than at Wooster, and the effect of the fertilizers is found chiefly in the straw at Columbus and more largely in the grain at Wooster. While the unfertilized yield of grain is but little larger at Wooster than at Columbus, during the second period, the yield on Plots 2 and 8 at Wooster is materially greater than that of the similarly fertilized Plots 11 and 12 at Columbus, although the yield of straw remains regularly larger at Columbus than at Wooster. In the case of the manured plots, however, there is no practical difference between the yields of grain over the two periods at Columbus, nor between these yields and that at Wooster, although in this case again the straw yield runs much larger at Columbus. This difference in yield of straw will be again referred to in discussing the experiments on wheat.

The yields in the two experiments, as compared with the average yields over similar periods for the counties within which they are located, are given below:

TABLE XXI. YIELDS PER ACRE OF OATS IN EXPERIMENTS, COMPARED WITH COUNTY YIELDS.

Place and period	Experiment station				County
	Unfertilized	Nitrate of soda 160 lbs.	Nitrate of soda 320 lbs.	Barnyard manure	
Columbus:—		Plot 11	Plot 12	Plot 20	Franklin
5 years, 1889–1893	34.8	42.7	42.6	36.0	22.3
5 years, 1894–1898	26.8	34.8	38.4	35.9	26.3
Wooster:—		Plot 2	Plot 8	Plot 6	Wayne
5 years, 1894–1898	30.9	42.9	48.7	45.4	36.3

It appears that the yield of oats in Franklin county has shown a marked increase during the second period of this test, while that in the experiment at Columbus has fallen off in every case except on the plot treated with barnyard manure, and here the failure to show a decline in yield may be ascribed to the relatively low yield during the first period. The unfertilized yield in the experiment, however, remains slightly above the yield of the county, while the fertilized yield is considerably higher.

In the experiment at Wooster the unfertilized yield falls below the average yield of Wayne county, but the fertilized yield is here, as at Columbus, considerably higher than the yield of the county.

It will be observed that the yield of Wayne county is much higher than that of Franklin county, a fact due chiefly to climatic causes. The yields of both oats and wheat in Ohio regularly increase in passing from the southern to the northern parts of the state.

In considering these comparative yields it is important to take into account the methods usually followed in the cultivation of oats in Ohio. As a rule this crop is sown upon corn stubble, and it is a common practice, especially in the southern part of the state, to sow the seed grain broadcast on the unplowed corn stubble and cover it in with corn cultivators. On low, black or sandy soils this method may be a useful one, but in the cultural experiments of this Station the yield of oats has been increased by 50 per cent. by more thorough preparation of the seed bed.*

The relatively low yield of Franklin county, as compared with the unfertilized yield in the long continued experiment in that county, is most probably chiefly due to the method of seeding indicated, the seed bed in the experiment having been thoroughly prepared each spring by plowing and harrowing, the grain being then sown with the drill.

The yield of Wayne county, however, lies between the unfertilized and the fertilized yields of the experiment at Wooster. Taking the five years, 1894 to 1898, the fertilized plots at Wooster show practically the same increase over the similarly fertilized plots at Columbus as is shown by the yield of Wayne county over that of Franklin.

The comparison as a whole confirms that of the experiments with corn in showing that the soil at Wooster is more responsive to fertilizers than that at Columbus.

FERTILIZERS ON WHEAT GROWN CONTINUOUSLY ON THE SAME LAND.

The experiment in the continuous culture of wheat was begun at Columbus with the crop sown in the fall of 1888. The land occupied by this test lies adjoining that devoted to corn and oats, but is farther from the river, and instead of having the gravelly subsoil found under the corn and oats plots the soil of the wheat plots rests directly upon the bowlder clay of the glacial drift. The land was in clover in 1888. In 1889 the wheat averaged nearly 43 bushels per acre on the unfertilized plots; in 1890 and 1891 these plots produced over 31 bushels per acre; in 1892 and 1893, 26½ bushels; in 1894 the crop fell to 16.3 bushels, and in 1895 and 1896 it suffered from the general destruction from winter killing, which prevailed over the state at large, especially on clay lands. In 1895 the yield fell to less than two bushels; and in 1896 the destruction was practically complete, both on the fertilized plots and where barnyard manure had been liberally used for eight years in succession.

* Bulletin 101.

Up to this year the fertilizers and manure had been regularly applied according to the plan given on page 28, making 8 successive applications; but at this point it was decided to stop fertilizing the wheat crop in this test for a few years, in order to study the residual effect of the previous applications. The crop of 1897 was a large one, the unfertilized yield averaging 39 bushels per acre; that of 1898 averaged nearly 20 bushels and that of 1899 fell to 13.7 bushels. In Table XXII are given the average yields and increase in this test for the first seven years, and for the three years since the fertilizing was stopped.

The table shows that the increase of grain in this experiment has been small, that for the complete fertilizers amounting to only five or six bushels per acre during the years while the fertilizers were being applied; while potash alone has increased the crop by less than one bushel, nitrogen alone by but little more than a bushel, and phosphoric acid alone by a fraction over three bushels. With the straw, however, the case is quite different. On the unfertilized plots 97 pounds of straw has carried on the average a bushel of grain. Had this ratio of grain to straw been maintained on the fertilized plots the increase of grain on Plots 11 and 12 would have amounted to more than four times that actually found, or to 24 or 25 bushels per acre, and that on the manured plots would have exceeded 20 bushels.

It will be observed, moreover, that the phosphoric acid of the fertilizer has been at least an equal factor with the nitrogen in increasing the weight of straw. From the second year of the test the plots receiving superphosphate have become conspicuous by their taller growth within two or three weeks after the grain was sown, and have remained so until harvest. This improvement has been most distinctly marked in the straw, however; the foliage has remained pale, and on Plots 2 and 8 the plants have had a spindling, anæmic appearance, while even on those plots which had had a small dressing of dried blood in the fall, following a larger application of nitrate of soda each spring before, the plants took on a much darker color and showed a more vigorous growth when the nitrate was again applied in April. The smaller applications of nitrate of soda have seldom caused the grain to lodge, but lodging has been frequent on Plot 12, and so common on Plot 14 as to reduce the total weight of straw both by the longer stubble left and by actual deterioration of the plant. On this plot the effort has been made to overcome the tendency to lodge by distributing the applications of nitrate, but without any evident effect. It has seemed that this tendency to lodge was due more largely to increased weight of foliage than to larger growth of straw. Turning to the later years of the test, it appears that the increase found since the discontinuance of the fertilizers has been chiefly due to the phosphoric acid. Instead of an increase an actual decrease of crop is found on the plots which had received nitrogen and potash alone, but there seems still to be a further increase where both were added to the phosphoric acid.

TABLE XXII. FERTILIZERS ON WHEAT GROWN CONTINUOUSLY AT COLULBUS.

Average yield and increase or decrease (—) in pounds per acre.

Plot	7 years, 1889 to 1895				3 years, 1897 to 1899			
	Yield		Increase		Yield		Increase	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
1	1,652	2,830	.....	.....	1,563	2,457	.....	.....
2	1,796	3,278	192	572	1,723	2,830	200	509
3	1,601	2,521	47	—60	1,471	2,146	—12	—40
4	1,506	2,457	.....	.....	1,443	2,050	.....	.....
5	1,625	2,699	76	180	1,374	2,129	—100	—15
6	1,705	3,270	112	689	1,637	2,526	133	288
7	1,636	2,643	.....	.....	1,535	2,332	.....	.....
8	1,772	3,182	162	595	1,839	2,844	328	573
9	1,763	3,106	179	575	1,603	2,416	117	207
10	1,558	2,476	.....	.....	1,462	2,148	.....	.....
11	1,877	3,889	327	1412	1,731	2,876	264	678
12	1,912	3,949	370	1472	1,805	2,885	334	638
13	1,535	2,477	.....	.....	1,476	2,297	.....	.....
14	1,860	3,751	347	1321	1,760	2,743	334	572
15	1,781	3,357	290	976	1,604	2,566	227	521
16	1,469	2,334	.....	.....	1,327	1,919	.....	.....
17	1,741	3,184	284	882	1,492	2,325	122	280
18	1,764	3,261	320	992	1,657	2,622	245	450
19	1,432	2,236	.....	.....	1,455	2,298	.....	.....
20	1,775	3,356	384	1205	1,835	3,172	421	964
21	1,702	3,079	352	1011	1,443	2,293	70	174
22	1,310	1,985	.....	.....	1,332	2,028	.....	.....
*	1,512	2,430	.....	.....	1,449	2,191	.....	.....

*Average of unfertilized plots.

The increase on the plot dressed with barnyard manure is greater than during the years when it was annually applied, and this not because of falling off in yield of unfertilized plots, but because the actual yield is greater.

The effect of phosphoric acid upon the wheat crop is quite different from that observed upon the corn and oats crops in this experiment, but it would seem that this difference is rather due to differences in soil than to preferences of crop, for we find in the experiments at Wooster and Strongsville no such differences in the effect of phosphoric acid upon these crops as that observed here.

A probable explanation of this difference at Columbus lies in the fact, already referred to, that the corn and oats have grown upon a soil lying upon and chiefly formed from a terrace-kame, the gravels of which contain a considerable proportion of limestone, brought down from the upper beds of the Corniferous limestone, which the Olentangy river cuts into a few miles above. One of the upper layers of this limestone has been shown by the late Edward Orton, State Geologist, to be so largely

TABLE XXIII: FERTILIZERS ON WHEAT GROWN CONTINUOUSLY AT WOOSTER.

Fertilizers, yield and increase in pounds per acre.

Plot	Fertilizers per acre annually			6-year average yield and increase			
	Super-phos-phate	Muriate of potash	Nitrate of soda and dried blood	Yield		Increase	
				Grain	Straw	Grain	Straw
1				556	1175		
2	160	100	160	1172	2183	619	1083
3	45	30	160	923	1632	375	609
4				545	947		
5	*			743	1383	201	428
6	**			897	1688	356	726
7				538	970		
8	160	100	320	1261	2491	723	1516
9	90	60	320	1118	2084	590	1104
10				523	985		
Average unfertilized yield				541	1019		

* Barnyard manure, 5,000 pounds per acre.
** Barnyard manure, 10,000 pounds per acre.

TABLE XXIV: COMPARISON OF YIELDS OF WHEAT GROWN CONTINUOUSLY IN STATION EXPERIMENTS WITH AVERAGE COUNTY YIELDS.

Yields in bushels per acre.

Year	Columbus			Frank-lin county	Wooster			Wayne county
	Unfer-tilized	Plot 11	Plot 20		Unfer-tilized	Plot 2	Plot 6	
1889	42.8	49.5	44.5	13.3				20.3
1890	31.1	36.9	34.7	14.2				18.0
1891	31.4	28.8	27.3	17.0				15.6
1892	26.5	29.1	25.4	16.0				14.1
1893	26.4	38.6	37.3	16.1				21.9
1894	16.3	23.7	25.3	13.1				22.0
6- year average	29.1	34.4	32.4	14.9				18.6
1895	1.9	12.4	12.5	9.6	4.9	14.8	10.5	10.3
1896	0.0	0.0	0.0	2.2	1.1	6.1	5.3	6.2
1897	39.1	37.5	35.0	18.2	20.4	32.8	29.1	21.4
1898	19.7	24.6	31.7	13.8	11.7	26.2	20.6	16.7
1899	13.7	24.4	25.1	*15.0	3.7	18.2	10.8	*16.0
5- year average	14.9	19.8	20.9	11.8	8.4	19.6	15.3	14.1

* October estimates of the State Department of Agriculture.

composed of the remains of the teeth, plates and bones of fishes as to merit the name of "bone bed." It is only about 6 inches in thickness, and its analysis indicates only about 17 per cent. of bone phosphate, hence it offers little encouragement to the exploiter of mineral phosphates, in the face of the enormous deposits of rocks showing a much higher percentage of phosphoric acid which are found in the southern states, but it will be seen that it may exert a notable influence on soils situated like the one here described.

Table XXIII gives the results of the experiment in the continuous culture of wheat at Wooster and shows a far lower rate of yield than that shown at Columbus in Table XXII; that table, however, excludes the year of most complete destruction, 1896, from the averages. In Table XXIV is given a comparison of the yields in these two experiments, both with each other and with the average yields of the counties in which they are located, the yields for 1896 being included. The yield at Wooster for 1894 has been excluded from this comparison, because all the seed wheat sown for the crop of that year at Wooster was treated with copper sulphate to destroy the smut, with the result that while the smut was completely eradicated the vitality of much of the seed was also destroyed and the crop was greatly reduced in consequence.

It appears from Table XXIV that the average unfertilized yield of the wheat grown continuously at Columbus was nearly double that of Franklin county during the first six years of this test and has been 25 per cent. greater during the last five years. The table also shows that during the period when both tests were in progress, the unfertilized plots at Columbus have out-yielded the similarly treated plots at Wooster by more than 75 per cent; but the complete fertilizer, applied to Plot 11 at Columbus and Plot 2 at Wooster, has brought up the yield to practically the same point in both tests, thus suggesting again the greater responsiveness to fertilizers of the Wayne county soil. The barnyard manure, however, shows as yet a larger yield at Columbus; but it must be remembered that the quantity used there is one-third larger than at Wooster, and that it had been applied continuously at Columbus for five years before the test began at Wooster. During the five years of the test at Wooster the manured plot has slightly surpassed in yield the average wheat field of Wayne county, while the unmanured plots have fallen far below that average. This point is explained by the comparatively run down condition of the soil on which the experiment is located, and by the fact that the farmers of Wayne county have purchased annually, during the period under consideration, about 80 pounds of commercial fertilizer for every acre sown, which has been practically all applied to the wheat crop.

Following our previous comparisons of continuous with rotative cropping, and of the experimental crops with average county yields, let us consider Table XXV, in which the average yields of the three experi-

TABLE XXV. YIELD OF WHEAT IN ROTATION IN STATION EXPERIMENTS AS COMPARED WITH YIELD OF WAYNE COUNTY.

Yield in bushels per acre.

Year	Continuous culture			5-year rotation			3-year rotation			Wayne Co.
	Unfertilized	Plot 2	Plot 6	Unfertilized	Plot 11	Plot 18	Unfertilized	Plot 11	Plot 18	
1895 ..	4.9	14.8	10.5	3.0	10.8	6.4	7.5	16.2	9.7	10.3
1896 ..	1.1	6.1	5.3	1.1	9.0	7.0	7.4	15.2	11.8	6.2
1897 ..	20.4	32.8	29.1	10.4	30.6	17.4	34.2	45.0	34.3	21.4
1898 ..	11.7	26.2	20.6	12.6	33.7	15.5	23.0	33.2	27.9	16.7
1899 ..	3.7	18.2	10.8	6.9	22.8	15.8	25.9	39.0	33.1	*16.0
Aver'e	8.4	19.6	15.3	6.8	21.4	12.4	19.6	29.7	23.4	14.1

ments at Wooster, thus far considered, are compared with each other and with the average yield of Wayne county.

It appears from this table that the average yield of wheat grown in the longer rotation has been even lower than that grown continuously on the same land; but this is chiefly due to the low yield of the rotative wheat in 1897, when it grew upon Section E, the poorest of the five sections in this test. It could not be expected, however, that there would be much superiority shown at this stage of the test, in a rotation in which there is but one year of clover to four years of exhaustive cereal cropping. When we compare either of these tests with the shorter rotation, a marked difference is at once apparent. The unfertilized yield here is more than double that in either of the other tests, and more than one-third greater than the average yield of the county, while the yield of the manured plot is 60 per cent., and that of the fertilized plot more than 100 per cent. greater than that of the county.

The superior yield of the crops grown in this shorter rotation, however, cannot be altogether ascribed to the method of culture. As has already been stated, the land employed in this rotation was in part (about half) cleared from the forest at the beginning of this test, while the remainder has been managed by a careful owner, whereas that used in the longer rotation had been rented for many years. That the two soils did not originally differ materially in productiveness is shown by the following facts:

The first crop grown in the longer rotation was corn, grown on Section C in 1893.* In recording the yields of the unfertilized plots in this crop it was observed that they ran uniformly at about 20 bushels per acre until No. 28 was reached, when the yield suddenly rose to 34 bushels. A careful examination of the field indicated that there had, at one time,

* This crop has not been included in the general averages heretofore given, because of changes in the plan of fertilizing for subsequent crops.

been a lane across the field at this point—an extension of the road shown on the farm map accompanying—which led from the barn (No. 7) to the wooded ravine east of the plots. Upon inquiry of the former owners of the land it was learned that there had been such a lane but that it had been abandoned and thrown into the field some seven years before the land came into possession of the Station. The comparative yields of Plot 28 and of the unfertilized plots which had been under constant cropping since the original clearing away of the forest, are shown in Table XXVI, to which is added a column showing the average yield of the several seasons for Wayne county.

TABLE XXVI. COMPARISON OF UNFERTILIZED PLOTS WITH COUNTY YIELDS

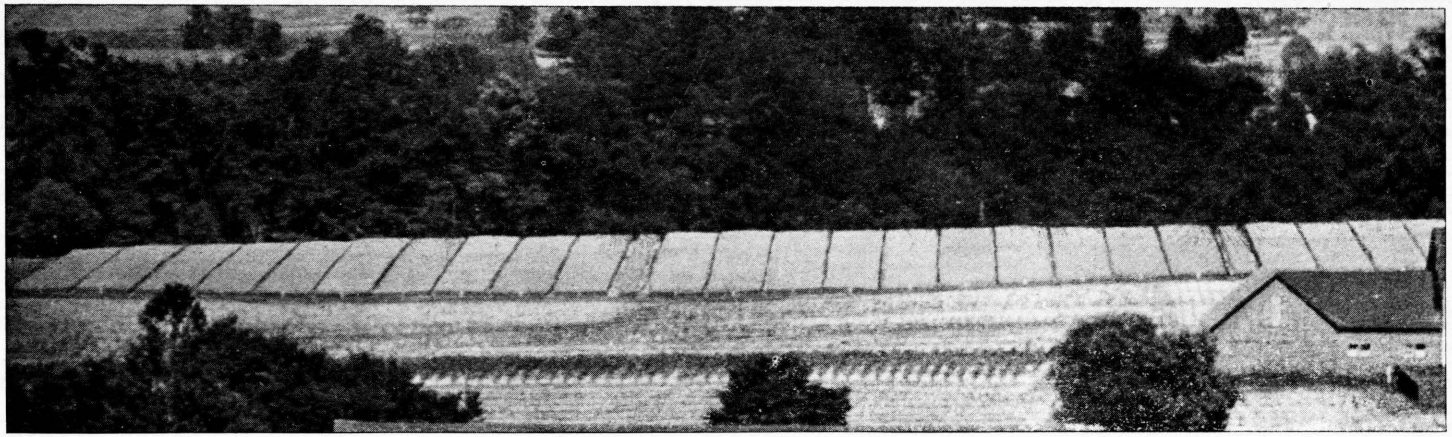
Year	Crop	Yield per acre		
		Unfertilized plots		Wayne county
		28	1 to 25	
1893	Corn	34.0 bus.	20.1 bus.	22.4 bus.
1894	Oats	35.8 "	24.5 "	35.2 "
1895	Wheat	7.2 "	2.5 "	10.3 "
1896	Clover hay	2400 lbs.	1390 lbs.	2400 lbs.
1897	Timothy	2800 "	2558 "	2960 "
1898	Corn	44.9 bus.	25.7 bus.	42.0 bus.
1899	Oats	33.9 "	31.4 "	†42.0 "

† October estimate, State Department of Agriculture.

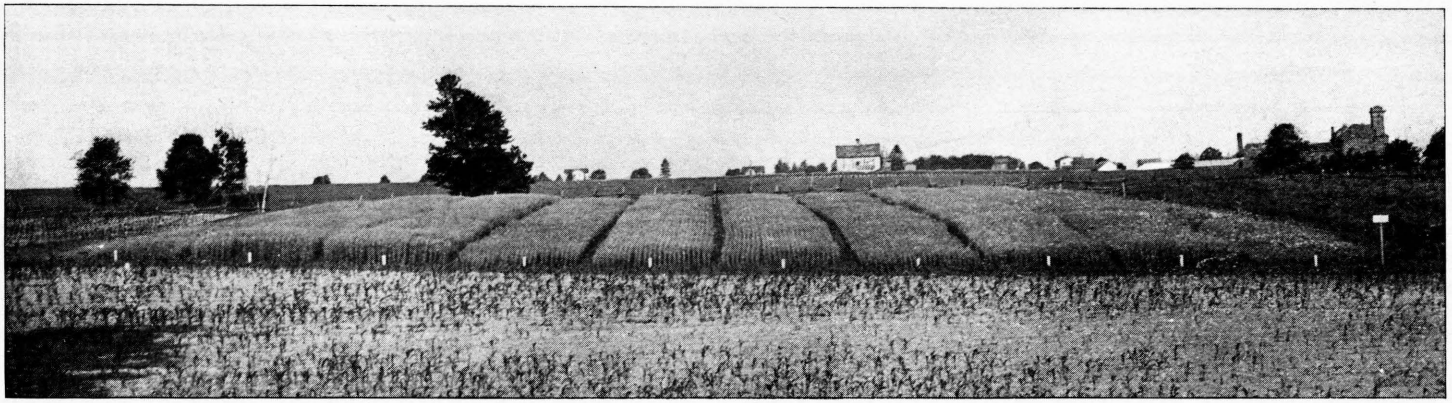
The only crop in this series which can be compared with those of the shorter rotation is the wheat crop, which is practically the same in both, and the clover crop, which is 2,400 pounds for Plot 28 in this case against 2,886 pounds as the average yield of the unfertilized hay in the short rotation for 1896. The yields of Plot 28 run, as a rule, quite close to those of the county, which, as already shown, are reëenforced by large purchases of commercial fertilizers. These yields on Plot 28 are the yields found in the continuous culture of crops in rotation with clover, but without any manure or fertilizer. They must, therefore, be taken as representing the capacity of a soil which has been somewhat reduced in natural fertility. This reduction, however, has been small, as compared with what many of the older fields of Wayne county have suffered, judging by the remaining unfertilized plots in this test.

The first settlements in what is now Wayne county were made during the first decade of the century. Wooster was laid out in 1808; the patents for the lands now occupied by the Experiment Station were issued under President Monroe in 1821, and it is probable that the portion occupied

PLATE VIII.



OATS ON SECTION C, 5-YEAR ROTATION,
as seen from the tower of the main building, half a mile west. Taken in July, 1899.



OATS IN CONTINUOUS CULTURE.
The fifth consecutive crop at Wooster. The plots are numbered from right to left. Taken in July, 1898.

by the longer rotation in these experiments has been in cultivation for at least 50 or 60 years.

The character of this soil, both in physical and chemical constitution and in the natural drainage furnished by the slow decay of the roots of the white oak, with which it was originally covered, rendered it especially adapted to the culture of wheat; and under the careful tillage of the thrifty Pennsylvania-German farmers, who were the original settlers of this region, Wayne county became noted for its wheat production, and the culture of this cereal increased until for many years more than one-seventh of the entire area has been annually sown in wheat.

The Wayne county farmers for many years followed the traditions of their Pennsylvania ancestors, in the keeping of live stock and the use of barnyard manure; but with the depression in live stock values, following the first exploitation of the western ranges, and the coincident introduction of commercial fertilizers, they parted with their cattle and sheep and began the purchase of fertilizers to such an extent that the number of cattle kept in the county fell from 31,000 in 1881 to 20,000 in 1897, and the number of sheep from 50,000 to 22,000, during the same period, while the expenditure for fertilizers has risen to an average of more than $40,000 annually.

During the 20 years, 1850 to 1869, the wheat yield of Wayne county rose from 12½ to 16 bushels per acre. This increase was accomplished under the old system of live stock husbandry. For the three decades since the average yields have been as follows:

1870–79	16.8	bushels per acre.
1880–89	16.9	" " "
1890–99	16.2	" " "

In other words, by a large and increasing expenditure for commercial fertilizers, the present generation of Wayne county farmers are able to maintain their wheat yield at the point to which their fathers brought it by live stock husbandry.

RATIO OF STRAW TO GRAIN.

The complaint is common in Ohio, especially on the rich, clay loams which characterize so large a proportion of the glacial drift, that it is much easier to produce straw than grain, and no question relating to soil management has been asked more earnestly of the Experiment Station than how to overcome this difficulty. It is common to assume that this excessive proportion of straw is due to an excess of available nitrogen in soil or fertilizer, but this does not seem to be a sufficient explanation.

In the experiments of this Station the relative yields of straw and grain have shown great variation in different seasons, the proportion of straw in the total produce being much greater in some seasons than in others, thus showing that climate is an important factor in determining

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the average ratio of any locality; but our experiments also show that other factors are also at work, some of which may be controlled by the farmer.

RATIO OF STRAW TO GRAIN IN WHEAT.

In Table XXVII is given the number of pounds of straw required to carry a bushel of wheat in the experiments of this Station, taking the average of all the unfertilized plots in each test, the fertilized plots from No. 2 to No. 12 inclusive, and the plots receiving 8 tons of barnyard manure at a dressing:

It will be seen from this table that in each of these experiments Plot 2, receiving phosphoric acid only, in superphosphate, has required more straw to carry a bushel of grain than the corresponding unfertilized plots, and the same is true of Plot 5, receiving nitrogen only, in dried blood and nitrate of soda. At Wooster and Neapolis the quantity of straw per bushel is greater on Plot 5 than on Plot 2, and at Columbus and Strongsville it is less. Where these two dressings are combined, on Plot 6, the ratio of straw to grain is increased in the first period at Columbus, but in none of the other tests does it rise above that found either on Plot 2 or on Plot 5, while in three of them it falls below either of the plots mentioned. When muriate of potash is added to the nitrogen and phosphoric acid (on Plot 11) the ratio of straw to grain makes a further advance in the Columbus test and remains nearly stationary in the longer of the two rotations at Strongsville, but in all the other tests it falls practically to the level of the unfertilized plots. A further addition of nitrate of soda (on Plot 12) does not materially increase the ratio of straw to grain, and the application of 8 tons of barnyard manure per acre apparently has approximately the same effect on this point as the use of this larger application of the more available form of nitrogen.

The plot receiving muriate of potash alone shows in every test, except the longer rotation at Wooster, a smaller weight of straw to the bushel of grain than is found on the unfertilized plots, and the combination of potash with phosphoric acid or nitrogen, either one without the other, shows generally a smaller quantity of straw per bushel of grain than is found where phosphoric acid is used alone or in combination with nitrogen.

In the case of the continuous cropping at Columbus, during the period when the fertilizer was being applied, and of both the longer rotations, the maximum yield of grain is invariably accompanied by a high yield of straw; but in the shorter rotations the ratio of straw to grain is no greater in case of the largest yields than on the unfertilized plots, and yet the maximum yield is much higher in the short rotations than in the longer ones.

Further light is shed upon this question by Plots 14 and 15 of the shorter rotation. Both these plots are heavily fertilized, receiving in each

TABLE XXVII. RATIO OF STRAW TO GRAIN IN WHEAT EXPERIMENTS.

Plot	Fertilizer	Columbus		Wooster		Strongsville		Neapolis
		First period, 7 crops	Second period, 3 crops	5-year rotation, 6 crops	3-year rotation, 5 crops	5-year rotation, 3 crops	3-year rotation, 3 crops	3-year rotation, 4 cr'ps
		Bushels per acre						
	Average unfertilized	25.21	24.15	9.28	19.59	6.80	9.76	12.03
2	Superphosphate	29.94	28.71	12.19	25.07	13.69	20.64	13.66
3	Muriate of potash	26.69	24.51	10.80	22.75	6.01	14.97	15.79
5	Nitrate of soda	27.09	22.90	11.14	22.23	6.60	11.33	14.96
6	Superphos. and nitrate	28.42	27.29	16.98	27.60	18.06	25.11	16.33
8	Superphos. and potash	29.53	30.65	15.18	27.77	14.56	23.89	14.79
9	Potash and nitrate	29.38	26.72	11.49	27.15	8.96	11.84	15.46
11	Superphos. potash & nitr	31.29	28.85	20.91	29.74	19.09	26.30	15.96
12	Superphos. potash & nitr	31.87	30.08	21.57	31.12	23.54	25.92	17 19
14	Superphos. potash & nitr	.....	.....	.....	32.07	.....	27.28	.....
15	Superphos. potash & nitr	.....	.....	.....	30.02	.....	23.11	.....
	Barnyard manure	29.58	30.58	13.18	23.38	17.70	17.06	.....
		Pounds of straw per bushel						
	Average unfertilized	97	91	105	98	95	93	88
2	Superphosphate	109	98	113	102	114	101	93
3	Muriate of potash	94	88	112	94	88	89	91
5	Nitrate of soda	100	93	117	107	97	98	97
6	Superphos. and nitrate	115	92	117	100	104	90	94
8	Superphos. and potash	108	93	102	91	98	88	92
9	Potash and nitrate	106	90	110	91	107	90	86
11	Superphos. potash & nitr	124	100	114	94	96	93	89
12	Superphos. potash & nitr	124	96	116	97	108	96	85
14	Superphos. potash & nitr	.....	.....	.....	95	.....	94	.....
15	Superphos. potash & nitr	.....	.....	.....	90	.....	93	.....
	Barnyard manure	114	104	125	96	100	92	.....

three years' course a total of 1,100 pounds of fertilizing material, against 1,300 pounds, distributed over five years, in the longer rotation. On Plot 14, in the shorter rotation, the fertilizer is divided between the potatoes and wheat, about two-thirds of the whole being given to the potatoes, while on Plot 15 the entire quantity is given to the potatoes. The result is a 5-year average on Plot 14 of 32 bushels of wheat per acre at Wooster and a 3-year average of 27 bushels at Strongsville, this being the maximum yields in the two experiments, and attained with a relatively low ratio of straw to grain.

THE RATIO OF STRAW TO GRAIN IN OATS.

Table XXVIII gives for the oats crops similar data to those previously given for wheat. It appears from this table that superphosphate

TABLE XXVIII. RATIO OF STRAW TO GRAIN IN OATS EXPERIMENTS

Plot	Fertilizers	Columbus		Wooster	Str'gsville
		First period	Second period		
	Bushels per acre				
	Average unfertilized	34.84	26.81	30.91	32.87
2	Superphosphate	.....	26.32	39.07	41.97
3	Muriate of potash	38.30	.....	34.71	33.77
5	Nitrate of soda	37.16	31.37	36.25	31.72
6	Superphosphate and nitrate	38.34	36.00	42.41	44.94
8	Superphosphate and potash	35.62	29.91	40.11	43.51
9	Potash and nitrate	39.52	34.50	34.13	36.20
11	Superphosphate, potash and nitrate	42.66	34.76	46.10	48.41
12	Superphosphate, potash and nitrate	42.60	38.42	47.27	49.93
14	Superphosphate, potash and nitrate	40.74	37.06	*37.85	*40.90
	Superphosphate, potash and sulph. ammonia	40.78	35.87	45.68	48.96
	Barnyard manure	35.98	35.92	*38.31	*39.20
	Pounds of straw per bushel				
	Average unfertilized	71	54	39	39
2	Superphosphate	.....	57	35	39
3	Muriate of potash	71	.....	36	37
5	Nitrate of soda	74	61	36	39
6	Superphosphate and nitrate	71	57	37	36
8	Superphosphate and potash	76	53	37	37
9	Potash and nitrate	72	60	35	40
11	Superphosphate, potash and nitrate	69	68	40	41
12	Superphosphate, potash and nitrate	72	70	42	41
14	Superphosphate, potash and nitrate	72	78	40	39
	Superphosphate, potash and sulph. ammonia	70	66	41	46
	Barnyard manure	74	67	38	37

* Fertilizers and manure applied to the corn crop; oats following, unfertilized.

used alone, has had a similar effect at Columbus in increasing the relative weight of straw in oats to that observed in wheat, while it has failed to produce any increase in the weight of grain; at Wooster and Strongsville, however, it has had the opposite effect, producing a marked increase of grain without increasing the ratio of straw. In fact a decrease in this ratio is shown at Wooster. Muriate of potash and nitrate of soda used separately have apparently produced an actual, though small, increase of crop at Columbus and Wooster, with negative results at Strongsville. They seem not to have materially affected the ratio of straw. A decided increase of crop in all the tests is shown by the combination of superphosphate and nitrate of soda, on Plot 6, and this is accomplished not only without increase, but with a small reduction in the relative weight of straw. When muriate of potash is added to the dressing, on Plot 11, there is a further increase of crop, in which the straw seems to take the

TABLE XXIX. RATIO OF STOVER TO EAR-CORN IN CORN EXPERIMENTS.

Plot	Fertilizers	Columbus		Wooster 5-year rotation, 6 crops	Strg'sville 5-year rotation, 4crops
		First period, 5 crops	Second period, 6 crops		
		Bushels per acre			
	Average unfertilized	64.27	33.76	31.89	27.90
2	Superphosphate	63.98	34.54	36.02	30.30
3	Muriate of potash	65.42	40.39	34.93	25.93
5	Nitrate of soda	70.50	41.51	35.38	24.11
6	Superphosphate and nitrate	71.86	39.69	43.32	29.66
8	Superphosphate and potash	65.96	41.20	40.11	27.79
9	Potash and nitrate	71.80	41.10	33.00	25.75
11	Superphosphate, potash and nitrate	70.56	41.94	41.28	37.43
12	Superphosphate, potash and nitrate	72.14	41.23	41.07	36.23
	Barnyard manure	67.68	36.59	40.73	38.68
		Pounds of stover per bushel			
	Average unfertilized	61	50	51	55
2	Superphosphate	59	50	45	45
3	Muriate of potash	68	51	49	49
5	Nitrate of soda	69	51	47	53
6	Superphosphate and nitrate	65	53	42	45
8	Superphosphate and potash	68	56	46	43
9	Potash and nitrate	67	50	50	51
11	Superphosphate, potash and nitrate	64	56	44	44
12	Superphosphate, potash and nitrate	63	52	44	46
	Barnyard manure	59	51	50	47

lead, and this tendency is more definitely shown on Plot 12, with an increase of nitrate of soda in the dressing. When we reach Plot 14, in the work at Wooster and Strongsville, on which the fertilizers are applied only to the wheat and corn, there is a considerable reduction in the yield per acre, although it still remains well above the unfertilized yield, while the relative yield of straw remains practically the same as on the unfertilized plots. On the plots where barnyard manure is used on the preceding crops the relative yield of straw falls below that on the unfertilized plots.

RATIO OF STOVER TO EAR-CORN.

In Table XXIX the ratio of stover to ear-corn is compared, as found in the two periods of the continuous cropping at Columbus, and in the rotative cropping at Wooster and Strongsville. From this table it will be seen that in the experiment in continuous culture at Columbus the general tendency of the fertilizers has been with corn, as with wheat and oats, to increase the total weight of plant more rapidly than that of grain; the only exceptions to this tendency in corn being found in the

case of superphosphate, used alone, and of barnyard manure. The superphosphate, however, in this case as on oats, fails to produce any increase of crop at Columbus, contrary to its action on wheat, and quite contrary to its action at Wooster and Strongsville. The probable explanation of this fact has already been given (pp. 40, 42).

At Wooster and Strongsville the fertilizers and manure appear to cause in every case a larger increase of grain than of stover.

RATIO OF STRAW AND STOVER TO GRAIN AS AFFECTED BY CONTINUOUS CROPPING.

It will have been observed that the ratio of straw and stover to grain is constantly larger at Columbus than in the more northerly tests. That this difference is not altogether due to the effect of continuous, as compared with rotative cropping, is shown by Table XXX, in which are given the results of the experiments with corn, wheat and oats, grown in continuous culture at Wooster, which show that the ratio of straw and stover to grain in this continuous cropping is as yet not higher than in the rotative cropping on the same land (See Tables XXVII, XXVIII and XXIX), it being remembered that the soil on which these tests are located is of the same character and has had the same previous history as that carrying the experiment in which the same crops are grown in rotation. Here we find that the light dressings of barnyard manure produce a uniform increase in both grain and straw, in the case of oats, and a larger increase of grain than of stover in the case of corn. The dressings of chemical fertilizers, on Plots 3 and 9, which approximate the composition of the plant (and also that of the manure) produce a larger increase of wheat and oats than the manure, but practically the same increase of corn, and in this increase the grain bears a relatively smaller proportion in wheat and corn. When this dressing is reënforced by additional quantities of superphosphate and muriate of potash, on Plots 2 and 8, there is a further increase of crop, in which the straw shows the larger gain in wheat and oats, but in corn the relative gain still remains approximately uniform. When we compare the plots receiving 160 pounds of nitrate of soda with those receiving 320 pounds, we find that the larger dressing of nitrate has apparently caused a large increase of straw in the case of wheat and oats, while the corn crop shows comparatively little effect, either in grain or straw.

It will be observed that in these tests the banryard manure has been more effective on corn than on oats or wheat, while the chemical fertilizers have shown greater effect on the oats and wheat. The response of the oats to the increase of nitrogen in the fertilizer is especially noteworthy, the 6-year average yield of 51 bushels per acre on plot 8 being the maximum yield thus far attained over so long a period in these tests.

Another difference between the habit of corn on the one hand, and

TABLE XXX.—RATIO OF STRAW OR STOVER TO GRAIN IN CROPS GROWN IN CONTINUOUS CULTURE AT WOOSTER.

Plot	Fertilizers per acre	Wheat		Oats		Corn	
		Bushels per acre	Pounds of straw per bush'l	Bushels per acre	Pounds of straw per bush'l	Bushels per acre	Lbs of Stover per bu.
	Average of unfertilized plots.....	9.01	113	28.00	36	26.26	51
5	Barnyard manure, 2½ tons.....	12.39	112	31.00	36	36.44	46
6	Barnyard manure, 5 tons.....	14.95	113	35.78	36	43.13	45
3	160 pounds nitrate of soda.... One-third ration superphos. and potash*	15.39	106	39.74	37	38.86	46
8	320 pounds nitrate of soda.... Two-thirds ration superphos. and potash*	18.64	107	49.11	42	42.76	44
2	160 pounds nitrate of soda.... 160 pounds superphosphate.... 100 pounds muriate of potash.	19.58	112	42.89	40	44.61	47
8	320 pounds nitrate of soda.... 160 pounds superphosphate.... 100 pounds muriate of potash..	21.01	119	51.30	43	44.43	45

*Approximately.

wheat and oats on the other, is shown in these tests in the general tendency of fertilizers and manure to increase the yield of straw, rather than grain, in the case of oats and wheat, while the opposite effect is generally observed in the case of corn.

Taken as a whole, these experiments would seem to justify the conclusion that in wheat and oats the normal balance between straw and grain may not always be found in the least proportion of straw in the entire plant, as such a condition may be but a manifestation of the phenomenon observed in many cases, in which a threatened impairment of vitality may abnormally stimulate the reproductive forces; but that this balance may be disturbed by the presence in the soil of a superabundance of one or more of the essential constituents of plant food, or by a deficiency of such constituents, or by unfavorable climatic conditions.

The experiments indicate that it is possible to increase the yield of grain to a high point without unduly increasing the weight of straw, and suggest that this may be accomplished by the culture of the cereals in systematic rotation with clover or other leguminous crops and with such cultivated crops as potatoes, roots or corn, crops which will bear liberal fertilizing, the fertilizers or manures to be applied largely to these crops rather than exclusively to the small grains.

One of the most obvious suggestions which these tests seem to offer is that the most effective system of maintaining fertility in such a rotation as the longer one employed in these experiments would be found in applying barnyard manure to the corn crop and following with moderate

dressings of chemical fertilizers on the oats and wheat. Such a system would permit the hauling of the barnyard manure direct from the stable to the field during the winter, thus not only economizing in labor but saving much of the loss which manure suffers on the average Ohio farm, by heating in neglected heaps in the barnyard.

EXPERIMENTS WITH BARNYARD MANURE.

The barnyard manure employed in the general experiments of this Station has purposely been treated according to the custom generally followed in Ohio; that is, as fast as accumulated during the winter it has been thrown into open yards, where it has been subjected to more or less trampling by stock, and has taken the rain for several months, before being spread upon the field.

The results obtained from this method of management, while such as to abundantly justify the making and use of manure, even in this loose manner, in preference to the purchase of chemical fertilizers, have nevertheless seemed to us considerably below what ought to be obtained. In the spring of 1897, therefore, an experiment was instituted on the following plan:

1. In cleaning out the cow stables certain portions of manure, taken from uniformly fed animals, are piled separately and dusted with one of the following materials, applying as nearly as possible two pounds of the material to every hundred pounds of manure:

(a) Finely ground, untreated phosphate rock (floats); (b) the same rock acidulated (acid phosphate); (c) kainit; (d) gypsum.

It is planned that the manure thus treated shall be subjected to the ordinary winter management of open-yard manure until plowing for corn begins in April, when it is spread upon permanent plots on a section of the East Farm.

2. About a week before time to begin plowing, manure is taken from box stalls, in which it has been trampled under foot while accumulating, without exposure to rain, and is divided into separate heaps and dusted with the materials named above, using the same proportions. This manure, after standing a few days, is spread upon duplicate plots, according to the plan accompanying. At the same time similar quantities of untreated manure are taken from the yard and from the box stall and spread upon other plots, and the whole is then plowed under to a shallow depth and prepared for planting.* Before planting two plots are dressed with commercial fertilizers, duplicating the applications given to Plots 11 and 30 in the 5-year rotation previously described.

The corn is followed by wheat without further manuring or fertilizing, and the wheat is to be followed by clover. Thus far, however, the

*For the crop of 1899 the manure was all spread after plowing.

TABLE XXXI: EXPERIMENTS WITH BARNYARD MANURE.

Yield and increase in pounds per acre.

Plot	Manures and fertilizers	Corn, (3 crops)				Wheat, (2 crops)			
		Yield		Increase		Yield		Increase	
		Ear-corn	Stov'r	Ear-corn	Stov'r	Grain	Straw	Grain	Straw
1	Unmanured	2,817	1,569	.....	.....	702	1,169	.....	.....
2	Yard manure and floats.	3,763	2,213	1,058	697	1,186	2,037	509	933
3	Stall manure and floats.	3,868	2,271	1,275	808	1,322	2,237	671	1,198
4	Unmanured	2,481	1,411	.....	.....	626	974	.....	.....
5	Yard manure and acid phosphate	3,520	1,998	1,121	648	1,186	1,965	560	978
6	Stall manure and acid phosphate	3,685	2,095	1,368	806	1,306	2,213	680	1,213
7	Unmanured	2,235	1,227	.....	.....	626	1,013	.....	.....
8	Yard manure and kainit.	3,429	1,873	1,089	565	1,182	2,081	520	1,053
9	Stall manure and kainit.	3,695	2,013	1,249	624	1,250	2,213	552	1,170
10	Unmanured	2,551	1,470	.....	.....	734	1,058	.....	.....
11	Unmanured	2,743	1,629	.....	.....	794	1,309	.....	.....
12	Yard manure & gypsum	3,800	2,299	1,090	711	1,178	2,077	460	902
13	Stall manure & gypsum	4,056	2,521	1,377	973	1,250	2,029	608	989
14	Unmanured	2,647	1,507	.....	.....	565	905	.....	.....
15	Yard manure alone	3,625	2,073	989	557	966	1,721	408	816
16	Stall manure alone	3,695	2,188	1,070	664	906	1,621	356	716
17	Unmanured	2,614	1,532	.....	.....	542	905	.....	.....
18	Chemical fertilizer A[1]	3,096	1,815	463	308	718	1,281	154	301
19	Chemical fertilizer B[2]	3,156	1,736	504	254	826	1,285	241	230
20	Unmanured	2,670	1,455	.....	.....	606	1,129	.....	.....
	Average unfertilized yield	2,595	1,471	.....	.....	649	1,058	.....	.....
	Average yield from yard manure	3,627	2,091	1,070	636	1,139	1,976	491	936
	Average yield from stall manure	3,800	2,218	1,268	775	1,207	2,063	572	1,057

[1] Chemical fertilizer A:—
Acid phosphate, 80 lbs. per acre
Muriate of potash, 80 " "
Nitrate of soda, 160 " "

[2] Chemical Fertilizer B:—
Acid phosphate, 100 lbs. per acre
Tankage, 100 " "
Muriate of potash, 10 " "

clover seeding has failed and soy beans have been grown instead, and the bean crop has been plowed under.

The object of this experiment, it will be seen, is to compare open-yard with covered-yard manure, and to test the effect, as preservatives or reënforcements, of the materials added to the manure.

The land on which the test is located was in oats in 1892; in 1893 it was plotted and drained and sown to wheat. In 1895 and 1896 it was in clover and timothy. No manure has been used upon it since it came into possession of the Station, until the beginning of this test. Table XXXI gives the results of the test to date.

The table shows that the stall manure has, in every instance, produced a larger total increase in the two crops than the yard manure, and

that the manures treated with either floats, acid phosphate, kainit or gypsum, have regularly produced a larger increase than those not so treated.

The average difference in favor of the stall manures amounts to 198 pounds of ear corn, 139 pounds of stover, 81 pounds of wheat and 121 pounds of straw per acre, the whole worth $2.21 per acre, at the low valuations previously employed, or 27 cents per ton of manure.

The average increase from the treated manures over those untreated amounts to $2.72 per acre, or 34 cents per ton of manure, by the same valuation, a difference amply sufficient to justify the use of any of the materials employed, at ordinary prices. In both crops the stall manure shows a decidedly larger gain from treatment than the yard manures; this point is shown in Table XXXII, which gives the excess in increase from each treated manure over the same description of manure untreated:

TABLE XXXII: EXCESS IN INCREASE FROM TREATED MANURES OVER UNTREATED.

Plot	Treatment	Excess in pounds per acre			
		Corn		Wheat	
		Ear-corn	Stover	Grain	Straw
2	Yard manure and floats	69	140	101	117
3	Stall manure and floats	205	144	315	382
5	Yard manure and acid phosphate	132	91	152	162
6	Stall manure and acid phosphate	298	142	324	497
8	Yard manure and kainit	100	8	112	237
9	Stall manure and kainit	179	40	196	454
12	Yard manure and gypsum	101	154	52	86
13	Stall manure and gypsum	307	309	252	273

The stall manure used in these tests has thus far been taken from bulls, these being the only animals kept constantly confined, and they have been fed on a maintainence ration only, whereas the cows furnishing the yard manure have been liberally fed for milk production; moreover, the yard manure has been exposed for but a few months at most, and in a level yard, subject neither to wash from eaves nor to that from higher ground. Its condition is very different from that of manure which has lain in a barnyard throughout a summer. It is believed, therefore, that the test shows only a part of the actual difference between what is actually realized from stable manure under average management and what might be realized.

The retail cost of the 40 pounds of material used for dusting a ton of manure has been about 20 cents for the floats, 30 cents for the acid phosphate, 36 cents for the kainit and 15 cents for the gypsum. The value of the average increase found in the corn and wheat crops thus far grown on Plot 15, receiving untreated yard manure, amounts to $11.08 per acre, or $1.38 per ton of manure. The value on Plot 16 is no greater, owing to the slightly lower yield of the more valuable wheat crop; but on all the other plots the stall manure gives a decidedly larger return than the yard manure, as shown in Table XXXIII, which gives the financial aspect of this experiment. The last two columns of this table give the net value of the increase per ton of manure, after deducting the cost of the material added.

TABLE XXXIII: GAIN FROM TREATMENT OF MANURE.

Material added	Value of increase per acre		Net value of increase per ton of manure	
	From yard manure	From stall manure	Yard	Stall
Nothing	$11.08	$10.97	$1.38	$1.37
Floats	12.87	16.17	1.31	1.82
Acid phosphate	13.71	16.74	1.41	1.79
Kainit	13.06	14.42	1.27	1.44
Gypsum	12.48	16.02	1.41	1.90

While this test has not yet been carried far enough to justify final conclusions, the results certainly lend encouragement to the belief that it is possible to realize a great deal more from barnyard manure than is now done in average farm practice.

It appears, at this stage of the experiment, that the chief value of the materials added lies in their arrest of escaping ammonia, rather than in actual plant food added.

THE RECOVERY OF FERTILIZING CONSTITUENTS.

In Table XXXIV is given the average percentages of water, potash and nitrogen found in the crops employed in these experiments, as determined by American analyses. From these analyses Table XXXV has been compiled, in which is shown the total quantity of phosphoric acid, potash and nitrogen applied during the course of the 5-year rotation in our experiments, the estimated number of pounds of each recovered in the combined average increase at Wooster and Strongsville, and the percentage which this recovery bears to the quantity applied in the fertilizer.

TABLE XXXIV. FERTILIZING CONSTITUENTS IN FARM CROPS[1]

Crops	Water	Phosphoric acid	Potash	Nitrogen
Corn (dent): — grain	10.6	.70	.40	[2]1.60
stover	10.2	.23	.99	[2]1.02
cobs	[3]7.9	[3].06	[3].60	[3].50
Oats: — grain	11.0	.89	.67	1.89
straw	9.2	.22	1.21	.64
Wheat (winter): —grain	10.5	.93	.64	[4]2.22
straw	9.6	.09	.72	.50
Clover hay	15.3	.36	2.10	1.98
Timothy hay	13.6	.33	1.42	.94
Potatoes	79.1	.12	.45	.34

[1] The analyses in this table are those published in the Annual Report of the New Jersey Experiment Station for 1896, except where otherwise noted.

[2] Analyses of this Station.

[3] Analyses of Massachusetts State Experiment Station.

[4] Average of 334 samples of Ohio wheat, including many differently named sorts, analyzed by this Station.

TABLE XXXV. FERTILIZING CONSTITUENTS APPLIED AND RECOVERED IN INCREASE IN ROTATIVE CROPPING

Plot	Pounds applied per acre			Pounds recovered per acre			Per cent. recovered		
	Phosphoric acid	Potash	Nitrogen	Phosphoric acid	Potash	Nitrogen	Phosphoric acid	Potash	Nitrogen
2	50.	.....	.....	10.15	24.64	29.79	20.	.....	.....
3	.....	130	.....	3.37	9.52	10.94	.....	7.3	.....
5	.....	.....	75	3.75	11.04	12.49	.....	.....	17
6	50.	.....	75	18.78	48.21	57.37	38.	.....	76
8	50.	130	.....	13.74	34.55	41.47	27.5	27	.....
9	.....	130	75	4.88	15.29	16.02	.....	12	21
11	50.	130	75	23.80	60.39	72.30	48.	46	96
12	50.	130	112	23 00	56.64	68.70	46.	44	61
14	37.5	90	50	18.88	50.77	59.87	50.	57	120
15	25.	65	25	12.48	25.65	34.69	50.	39	139
20	50.	10	12	17.47	49.24	55.55	35.	.....	.....

From this table it appears that when phosphoric acid has been applied alone, in superphosphate, 20 per cent. of the quantity applied in the fertilizer has been recovered in the increase of crop. When phosphoric acid has been reënforced with potash, there has been a recovery of 27 per cent. of the former. When phosphoric acid has been reënforced with nitrogen instead of potash the recovery has reached 38 per cent. of the phosphoric acid applied, and when both potash and nitrogen have been added the recovery of the phosphoric acid has amounted to 46 to 50 per cent.

When potash has been used alone, in the muriate, but 7 per cent. of that applied in the fertilizer has been recovered in the increase of crop. When it has been reënforced with nitrogen there has been a recovery of 12 per cent.; when phosphoric acid has been added instead of nitrogen, 27 per cent. of the potash has been recovered, and when both nitrogen and phosphoric acid were added, the recovery of potash has run from 44 to 57 per cent.

When nitrogen has been added alone, in nitrate of soda and a combination of nitrate of soda and dried blood, 17 per cent. of the nitrogen applied in the fertilizer is found in the increase; when the nitrogen is reënforced with potash, 21 per cent. of the nitrogen is recovered; when phosphoric acid is added instead of potash the recovery of nitrogen reaches 76 per cent., and when both phosphoric acid and potash are added, the total recovery of nitrogen has amounted to 96 per cent. of that applied in the fertilizer on Plot 11, and has considerably exceeded that proportion on Plots 14 and 15. It would seem, therefore, that the clover grown in this rotation is furnishing some excess of nitrogen, which the succeeding crops are able to utilize, when they are grown under conditions of relatively deficient nitrogen supply; but it is notable that the phosphoric acid and potash found in the increase never much exceed half that given in the fertilizer, however abundant the nitrogen supply may be. These points are graphically brought out by Diagram VIII, which shows that there has been an approximately uniform recovery of phosphoric acid and potash, with reference to each other, this recovery exceeding half the quantity applied in the fertilizer on one plot only, while there has been a very much higher proportionate recovery of nitrogen. The diagram also shows well the superior effectiveness of combination; the addition of an abundant supply of nitrogen nearly doubles the effectiveness of the pound of phosphoric acid (compare Plots 2 and 6) and the presence of an abundant supply of phosphoric acid more than quadruples the effectiveness of the pound of nitrogen (Plots 5 and 6); and when both phosphoric acid and potash are present in ample quantity, the effectiveness of the nitrogen is still further increased.

Further light is thrown on this point by the experiment in continuous culture, which is being carried on at Wooster parallel to the rotative cropping. In this experiment Plots 2 and 8 are fertilized similarly to Plots 11 and 12 in the rotation, the different fertilizing constituents being given in

DIAGRAM VIII. FERTILIZING CONSTITUENTS APPLIED PER ACRE IN FIVE-YEAR ROTATION AND PERCENTAGE RECOVERED IN INCREASE OF CROP.

Average of nine rotations.

Plot	Fertilizing constituents applied in 5 years: Phosphoric acid	Potash	Nitrogen
2	50	....	....
3	....	130	....
5	....	....	75
6	50	....	75
8	50	130	....
9	....	130	75
11	50	130	75
12	50	130	112
14	37.5	90	50
15	25	65	25
30	50	10	12

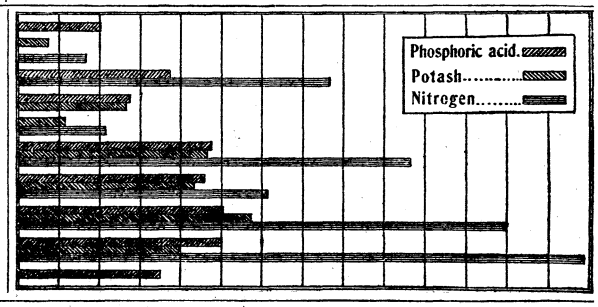


TABLE XXXVI. FERTILIZING CONSTITUENTS APPLIED PER ACRE AND RECOVERED IN INCREASE IN CONTINUOUS CROPPING.

Six-year average.

Crop	Plot No	Pounds applied: Phosphoric Acid	Potash	Nitrogen	Pounds recovered: Phosphoric Acid	Potash	Nitrogen	Percent recovered: Phosphoric Acid	Potash	Nitrogen
Corn ...	2	25.	50.	25.	8.08	11.33	22.67	32.3	22.7	90.7
	8	25.	50.	50.	10.50	14.27	28.94	42.0	28.5	57.9
	3	9.4	15.	25.	5.20	6.89	14.24	55.3	46.0	57.0
	9	18.8	30.	50.	10.13	13.81	27.65	53.9	46.0	55.3
Oats ...	2	19.5	50.	25.	6.26	13.02	14.67	25.0	26.0	58.7
	8	25.	50.	50.	8.92	18.28	20.86	35.7	36.6	41.7
	3	8.6	25.	25.	4.55	9.55	10.53	52.9	38.2	42.1
	9	17.2	50.	50.	7.91	16.16	18.48	46.0	32.3	37.0
Wheat .	2	25.	50.	25.	6.73	11.76	19.16	26.9	23.5	76.6
	8	25.	50.	50.	8.13	15.57	23.72	32.5	31.1	47.4
	3	7.	15.	25.	4.03	6.78	11.37	57.6	45.2	45.5
	9	14.	30.	50.	6.48	11.72	18.62	46.3	39.1	37.2

arbitrary quantities, while on Plots 3 and 9 the nitrogen remains the same, but the phosphoric acid and potash are reduced to quantities bearing approximately the same ratio to the nitrogen carried by 160 pounds or 320 pounds of nitrate of soda, as is indicated by the average analyses of the crops.

The general results of this test are given in Table XXXVI, which shows that when the three fertilizing constituents have been given in their theoretical ratio to each other (Plots 3 and 9) their recovery has varied within comparatively narrow limits, but in no case does the realization of the phosphoric acid or potash, nor the average of the three constituents, reach sixty per cent. of the amount applied.

When the relative quantities of phosphoric acid and potash are increased, on Plots 2 and 8, there is a considerable gain in the increase of crop, but this gain is made at a loss in average utilization of the fertilizing constituents, except the nitrogen, which shows a considerable increase. It will be observed that the average recovery, especially of nitrogen, is greater throughout in the case of the corn crop than of either oats or wheat, which is in harmony with general observation and experience on this point. It appears that the nitrogen of the nitrate of soda is relatively more available than the potash of the muriate, or the phosphoric acid of superphosphate (acid phosphate in this case), but in no case in this experiment of continuous cereal culture is all the nitrogen recovered, even from this, perhaps the most satisfactory in this respect of all commercial fertilizing materials.

The practical application of this study of the recovery of fertilizing constituents is to be found in a comparison of the cost of fertilizing materials with the value of the increase of crop produced by them.

A bushel of corn, with its cobs and stover, contains on the average about half a pound of phosphoric acid, three-fourths of a pound of potash and a pound and a half of nitrogen. Farmers who purchase mixed fertilizers from the retail dealers are paying in Ohio from 5 to 6 cents per pound for available phosphoric acid, from 6 to 8 cents for potash, and from 20 cents upward for nitrogen. At the lowest of these prices the phosphoric acid, potash and nitrogen found in a bushel of corn, with its cobs and stover, would cost 37 cents, or more than the corn is worth in the average market; but our experiments in continuous culture show that we would have to apply in the fertilizer at least twice as much phosphoric acid and potash, and from 10 to 80 per cent. more nitrogen than is found in the increase of crop, in attempting to produce corn by the aid of commercial fertilizers alone. This point may perhaps best be illustrated by Table XXXVII, in which is given the value of the increase and the cost of the fertilizing materials used to produce it in the experiments on crops grown in continuous culture.

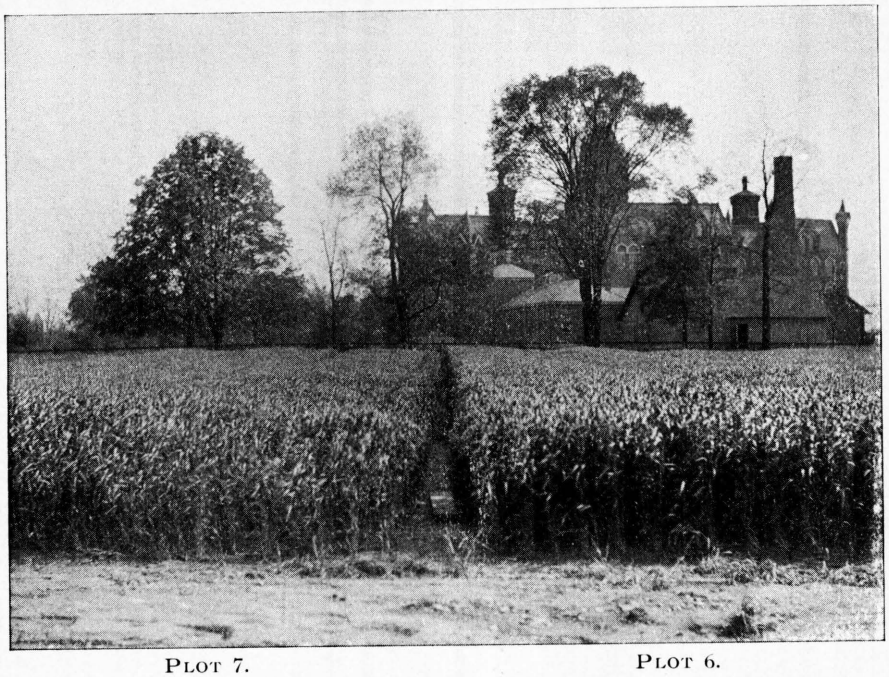
TABLE XXXVII. COST OF PRODUCING CROPS BY CHEMICAL FERTILIZERS ALONE.

Plot	Cost of fertilizers				Value of increase	Loss
	Phosphoric acid	Potash	Nitrogen	Total		
Corn.						
2	$1.25	$3.00	$5.00	$9.25	$6.76	$2.49
8	1.25	3.00	10.00	14.25	8.82	5.43
3	.47	.90	5.00	6.37	4.36	2.01
9	.94	1.80	10.00	12.74	8.53	4.21
Oats.						
2	1.25	3.00	5.00	9.25	4.85	4.40
8	1.25	3.00	10.00	14.25	6.94	7.31
3	.43	1.50	5.00	6.93	3.60	3.33
9	.86	3.00	10.00	13.86	6.16	7.70
Wheat.						
2	1.25	3.00	5.00	9.25	7.90	1.35
8	1.25	3.00	10.00	14.25	9.53	4.72
3	.35	.90	5.00	6.25	4.73	1.52
9	.70	1.80	10.00	12.50	7.59	4.91

It will be observed that the nitrogen is the chief factor of cost in the above estimates, and the question naturally arises, is it necessary to give so much nitrogen? The answer to this question is given in Table XXXVIII, which shows the total quantity of phosphoric acid, potash and nitrogen applied to each plot, the ratio which the nitrogen bears to the phosphoric acid and potash combined, the total quantity of these essential constituents recovered in the increase of crop, and the number of pounds recovered for each hundred pounds in the fertilizer.

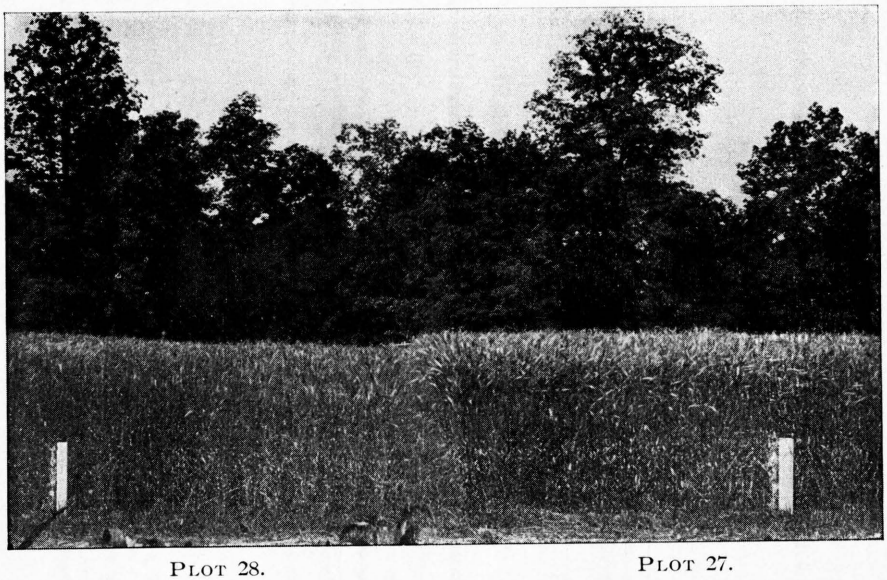
Comparing Plots 2 and 8, we see that the increase in the ratio of nitrogen in the fertilizer has increased the proportionate recovery of essential constituents, as shown by the last column of the table, in the case of corn and oats, and has maintained the ratio of recovery in the case of wheat, in the face of the general tendency to decrease in proportionate effectiveness with increase in total quantity of fertilizer. This last tendency probably accounts for the diminished effectiveness of the dressing on Plot 9, as compared with that on Plot 3, their dressings differing only in quantity, not in relative composition. That this, however, is not a sufficient explanation for the superior effectiveness of the application to Plot 3, is shown by the superiority of Plot 9 over Plot 2, although both receive practically the same total quantity of fertilizers.

The above result may be exhibited in another form in the following



PLOT 7. PLOT 6.

Wheat in continuous culture on the farm of the State University, Columbus.
Taken just before heading out.



PLOT 28. PLOT 27.

Wheat in 5-year rotation at Wooster, Section B. These views show that the effect of the fertilizer extends to the outside row of the plot to which it is applied, and stops there.

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TABLE XXXVIII. RECOVERY OF FERTILIZING CONSTITUENTS UNDER DIFFERENT RATIOS OF NITROGEN IN THE FERTILIZER.

Plot	Pounds of essential constituents in fertilizer	Ratio of nitrogen to phosphoric acid and potash	Pounds of essential constituents recovered	Constituents recovered per 100 pounds in fertilizer
		Corn.		
2	100	1:3	42.08	42
8	125.	2:3	53.71	43
3	49.4	3:3	26.38	53
9	98.8	3:3	51.59	52
		Oats.		
2	100	1:3	33.95	34
8	125	2:3	48.06	38
3	58.6	3:3	24.63	40
9	117.2	3:3	42.55	36
		Wheat.		
2	100	1:3	37.65	38
8	125	2:3	47.42	38
3	47	3:3	22.18	47
9	94	3:3	36.82	39

statement, which gives the value of the increase from 100 pounds of essential constituents in the fertilizer in these different combinations:

Value of increase from 100 pounds of essential constituents in fertilizer.

Plot	Corn	Oats	Wheat
2	$6.76	$4.85	$7.90
8	7.05	5.55	7.62
3	8.83	6.14	10.01
9	8.64	5.26	8.08

In short, in these experiments in continuous culture, the largest effect has been regularly produced when the three chief fertilizing constituents have been employed in approximately the same ratio to each other which they bear in the crops to which they are applied, as on Plots 3 and 9; but such a ratio involves the use of the costliest of the three, nitrogen, in such large proportion as to raise the cost of the increase produced to a point equal to or beyond its value in the market. It is true that the cost of the fertilizer may be reduced by from 20 to 50 per cent., and its efficiency may at the same time be increased, by purchasing such materials as those used in these experiments, rather than those found in the ordinary fertilizer compound; but even then the fact remains, that a considerable portion of the nitrogen required may be produced far more

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cheaply by the growing of clover and other leguminous crops, than by purchasing it in any artificial carrier.

In these experiments there has been an average increase over the 6 years in the oat crop, running from 387 pounds, or more than 12 bushels per acre on Plot 3, to 729 pounds, or nearly 23 bushels per acre on Plot 9. The wheat crop has been increased by an average of 375 pounds, or 6¼ bushels per acre on Plot 3, to 728 pounds, or more than 12 bushels per acre on Plot 8. The corn crop has been increased by an average of 692 pounds of ear-corn, or nearly 10 bushels per acre on Plot 3, to 1,418 pounds, or more than 20 bushels on Plot 8. These are high rates of increase, and they show that the failure to produce crops profitably, on purchased plant food solely, is not due to lack of response in the crops themselves.

RECOVERY OF CONSTITUENTS FROM BARNYARD MANURE.

On the basis of average analyses, the barnyard manure used on Plots 5 and 6 in the experiments in continuous culture should contain nitrogen equivalent to that found in 160 pounds and 320 pounds of nitrate of soda, with phosphoric acid and potash in quantities lying between those applied to Plots 3 and 9 on the one hand, and Plots 2 and 8 on the other. The results of the experiment indicate a considerably lower availability for these fertilizing constituents, as found in manure, than in the chemicals employed on the other plots, but they offer a useful suggestion as to the relative ability of the different crops to utilize the plant food in manure, as shown by Tables XXXIX and XL:

TABLE XXXIX. COMPARATIVE RECOVERY FROM BARNYARD MANURE.

Crop	Plot	Pounds of manure	Pounds of increase		Pounds recovered		
			Grain	Straw	Phosphoric Acid	Potash	Nitrogen
Oats	5	5,000	88	20	.74	.35	1.54
	6	10,000	242	252	2.71	4.66	6.19
Wheat	5	5,000	200	428	2.25	4.35	6.58
	6	10,000	357	726	3.97	7.51	11.56
Corn	5	5,000	631	282	4.25	5.57	11.58
	6	10,000	1,172	590	8.04	11.00	17.60

It will be observed that the wheat has recovered more than twice as much plant food from the manure as the oats, and the corn more than three times as much. This matter may be illustrated from the financial side by Table XL, which gives the value of the average increase from manure applied in different quantities to different crops and rotations of crops in the experiments at Wooster:

TABLE XI. VALUE OF INCREASE FROM BARNYARD MANURE.

Plot	Experiment	Manure per acre	Value of increase	
			Total	Per ton of manure
5	Continuous culture — Oats	2½ tons	$0.68	$0.27
6	" " "	5 "	2.19	44
5	" " Wheat	2½ "	2.63	1.05
6	" " "	5 "	4.65	93
5	" " Corn	2½ "	3.46	1.38
6	" " "	5 "	6.65	1.13
20	5-year rotation manured on corn and wheat	8 "	11.92	1.49
18	" " " "	16 "	17.83	1.11
17	3-year rotation manured on wheat	4 "	8.35	2.14
18	" " "	8 "	12.90	1.61
30	" " " potatoes	8 "	20.17	2.27

This table shows a steadily increasing financial return with crops grown continuously, from oats to wheat and from wheat to corn; it shows a slightly better return from the manure used in the long rotation than the best outcome from continuous cropping, and a still further increase in value of product in the shorter rotation, especially where the manure is applied to the potato crop. In every case, except in the oat crop, there is a somewhat higher return from a ton of manure in the smaller dressings than in the larger, but in most cases the increased gross return from the larger applications is sufficient to justify their use.

This greater relative productiveness of the smaller applications, especially as between the very small applications of 2½ tons and 5 tons per acre, would probably not have been realized except for the fine pulverization and uniform distribution of the manure given by the spreading machine, and it will be realized at once that this factor must add to the productiveness of the manure, whatever the quantity applied.

CARRIERS OF NITROGEN.

Plots 11, 21, 23 and 24 in the rotation experiments receive continuously the same quantities each of phosphoric acid, potash and nitrogen, the latter being given in nitrate of soda on Plot 11*, linseed oil-meal on Plot 21, dried blood on Plot 23 and sulphate of ammonia on Plot 24. Phosphoric acid was given in dissolved bone-black previous to 1897, and in acid phosphate since, and potash is given in the muriate, allowance being made on Plots 21 and 23 for the phosphoric acid and potash in the

* By referring to the plans of these experiments pp —— and ——, it will be seen that in all our tests nitrate of soda is given to wheat in combination with dried blood, about one-fourth the total nitrogen ration being given in dried blood in the Fall and the remainder in nitrate of soda in April.

TABLE XLI—VALUE OF AVERAGE INCREASE FROM DIFFERENT CARRIERS OF NITROGEN.

Crop	Culture	Number of crops gr'wn	Carriers of nitrogen							
			Nitrate of soda		Linseed oil-meal		Dried blood		Sulphate of ammonia	
			Average value of increase	Rank	Average value of increase	Rank	Average value of increase	Rank	Average value of increase	Rank
Corn ..	5-year rotation Wooster....	5	$4.24	1	$2.94	4	$3.10	3	$3.95	2
	5-year rotation Strongsville	4	3.75	1	2 71	2	1.98	4	2.16	3
	Continuous Columbus ..	11	2.80	1	. ...	.....	.....	.....	2 39	2
Oats ..	5-year rotation Wooster....	6	4.39	2	2.91	4	3.48	3	4.41	1
	5-year rotation Strongsville	4	3.67	3	3.33	4	4.10	2	4.59	1
	Continuous Columbus ..	10	2.22	2	...	....	. ..	.....	2.52	1
Wheat .	5-year rotation Wooster....	6	9.20	1	8.53	2	6.69	4	7.14	3
	5-year rotation Strongsville	3	9.27	1	6 87	4	7.83	3	8.49	2
	3-year rotation Wooster....	5	6.49	3	6.27	4	6.65	2	6.74	1
	3-year rotation Strongsville	3	12.61	1	10.70	2	10.08	3	9.06	4
	Continuous Columbus ..	7	5.01	1	.....	.....	.. ...	....	4.16	2
Hay ...	Hay, all tests .	17	1.95	1	1.71	3	1.81	2	1.43	4

SUMMARY.

Corn ..	5-year rotations ...	9	4.02	1	2.27	4	2.60	3	3.16	2
Oats ..	5-year rotations ...	10	4.10	2	3.16	4	3.73	3	4.33	1
Wheat .	Both rotations	17	9.03	1	7.89	2	7.48	4	7.56	3
Hay ...	" "	17	1.95	1	1.71	3	1.81	2	1.43	4

oil-meal and dried blood. At Columbus a similar comparison has been made between nitrate of soda and sulphate of ammonia, on Plots 11 and 15, but the 1,000 pounds of oil-meal per acre, used on Plot 21 in that test, carries an excess of nitrogen and a deficiency of phosphoric acid and potash, hence that plot cannot be compared with the oil-meal plots at Wooster and Strongsville.

The results of this comparison are given in Table XLI, which shows the value of the average increase per acre, as found in the different tests, with the relative rank of the nitrogen carriers. This table gives to nitrate of soda decidedly the first rank as a nitrogen carrier for corn and wheat, the only exception being found in the shorter rotation at Wooster, where, however, the difference is so small in all cases as to indicate a practical equality of all three carriers on that particular soil.

With oats, however, sulphate of ammonia has given the best results in every case, although the difference at Wooster is very small. Sulphate of ammonia takes, in the general average, the second place for corn, while the difference between dried blood and linseed oil-meal is so small that no decided superiority can be ascribed to either. If we consolidate the values given in the summary of this table, as representing the probable outcome of an average rotation, in which the four crops have followed each other as in our actual rotations, we shall have the following as the value of the total increase per acre from each carrier of nitrogen, when reënforced, as in these tests, with sufficient and uniform quantities of phosphoric acid and potash:

From nitrate of soda	$19.10
" sulphate of ammonia	16.48
" dried blood	15.62
" linseed oil-meal	15.03

Taking nitrate of soda as 100, these figures would give the following as the relative effectiveness of these nitrogen carriers.

Nitrate of soda	100
Sulphate of ammonia	86
Dried blood	82
Linseed oil-meal	79

CARRIERS OF PHOSPHORIC ACID.

The fertilizing of Plots 11, 26, 27 and 29 in the rotations at Wooster and Strongsville, and of Plots 11, 17 and 18 at Columbus, has been planned as a test of the availability of phosphoric acid in different carriers. The total quantity of phosphoric acid given in the different carriers is the same, as are also the quantities of nitrogen and potash, the nitrogen being given in nitrate of soda alone on corn and oats, or three-fourths nitrate of soda and one-fourth dried blood on wheat, except on Plot 26, where the

TABLE XLII. VALUE OF AVERAGE INCREASE FROM DIFFERENT CARRIERS OF PHOSPHORIC ACID

Crops	Culture	Number of crops gr'wn	Carriers of phosphoric acid							
			Acid phosphate		Raw bone-meal		Dissolved bone-black		Basic slag	
			Av'ge value of increase	Rank	Av'ge value of increase	Rank	Av'ge value of increase	Rank	Av'ge value of increase	Rank
Corn...	5-year rotation Wooster...	5	$3.42	1	$2.65	4	$3.33	3	$3.36	2
	5-year rotation Strongsville.	4	2.99	3	1.85	4	3.38	1	3.36	2
	Continuous Columbus..	11	3.41	1	.....	.....	2.33	3	3.11	2
Oats...	5-year rotation Wooster....	6	3.97	2	3.47	3	4.41	1	3.41	4
	5-year rotation Strongsville.	4	3.48	4	4.08	3	4.30	1	4.17	2
	Continuous Columbus..	10	2.30	2	...	.....	2.64	1	2.12	3
Wheat.	5-year rotation Wooster....	6	3.26	2	6.92	4	8.61	1	7.38	3
	5-year rotation Strongsville.	3	7.81	4	9.77	2	8.70	3	11.13	1
	3-year rotation Wooster....	5	6.39	4	7.54	3	7.66	2	8.11	1
	3-year rotation Strongsville.	3	12.99	3	13.20	2	10.58	4	13.68	1
	Continuous Columbus..	7	3.63	3	.....	.....	4.16	1	3.74	2
Hay ...	All tests.....	17	6.29	4	1.91	3	1.92	2	2.70	1
	SUMMARY.									
Corn...	5-year rotations.....	9	$3.23	3	$2.30	4	$3.35	2	$3.36	1
Oats...	5-year rotations.....	10	3.77	2	3.71	3	4.37	1	3.71	3
Wheat.	Both rotations	17	3.24	4	8.71	2	8.68	3	9.37	1
Hay ...	"	17	1.29	4	1.91	3	1.92	2	2.70	1

nitrogen in the bone meal takes the place of the dried blood and a part of the nitrate of soda. (See plans of fertilizing, pp. 10 and 21.)

Up to 1897, dissolved bone-black was used as the standard carrier of phosphoric acid in all our tests, but as acid phosphate has almost completely displaced dissolved bone-black in the fertilizers used in Ohio, it seemed desirable to use this material as our standard. This change was made in the spring of 1897, and at the same time the carrier of phosphoric acid on Plot 27, which had previously been acid phosphate, was changed to dissolved bone-black. Up to 1898 the acid phosphate used on this plot was made from South Carolina rock, and was used on the basis of 14 per cent. available phosphoric acid, against 16 per cent. available in the dissolved bone-black; but beginning with that season, Tennessee acid phosphate, 16 per cent. grade, has been substituted. The results of this comparison are given in Table XLII:

From this table it appears that basic slag has taken the first rank as a carrier of phosphoric acid on three crops, and the third by a very small margin, on the fourth; and that dissolved bone-black, acid phosphate and raw bone-meal follow, with but small differences between.

Making the same summing up in this test as in the case of the nitrogen comparison, we find that the total average value of increase from different carriers of phosphoric acid in the three crops, the nitrogen and potash remaining uniform, has been as follows:

From basic slag	$19.04
" dissolved bone-black	18.32
" raw bone-meal	16.63
" acid phosphate	16.53

Taking basic slag as 100, we find the following relative values of these materials as carriers of phosphoric acid:

Basic slag	100
Dissolved bone-black	96
Raw bone-meal	87
Acid phosphate	87

When results run so close together as they do in some of these comparisons further work is required to definitely determine their relative values.

The potatoes have not been included in these comparisons of carriers of nitrogen and phosphoric acid, for the reason that the general results on the plots used in these experiments have not, as yet, been sufficiently harmonious, in the case of potatoes, to justify their use.

SUMMARY.

On soils formed chiefly from the argillaceous shales of the Waverly series, phosphoric acid is found to be the constituent of fertility first required by corn, oats, wheat and potatoes; but the maximum yield has not been obtained until both nitrogen and potash were also added.

When used alone, or in combination with each other only, nitrogen and potash have produced but a very small increase, and have always been thus used at a heavy financial loss.

The complete fertilizer, containing all three constituents, has produced a much larger total increase than the sum of the increase produced by the constituents used separately.

When the cereal crops have been grown continuously on the same land the maximum increase of crop, per pound of fertilizing constituents applied, has been obtained when these constituents were used in approximately the same ratio to each other in which they are found in the crop; but the total recovery of fertilizing constituents in increase of crop, under continuous cropping, has never exceeded sixty per cent. of the quantity applied in the fertilizer.

When the cereals have been grown in rotation with clover the recovery of nitrogen has, under favorable conditions, exceeded the amount applied in the fertilizer; but even under these conditions the recovery of phosphoric acid and potash has remained far below the quantity applied in the fertilizer, when maximum yields were reached.

Thus far in these experiments, the surplus nitrogen accumulated by a crop of clover, the roots only being left in the ground, has not been more than sufficient to satisfy the demands of the one crop immediately following the clover.

At the prices at which mixed fertilizers are sold in Ohio the attempt to furnish all the nitrogen, as well as all the phosphoric acid and potash required to produce increase in cereal crops grown in continuous culture, has invariably resulted in pecuniary loss, although very large increase of crop has been thus produced.

The rotation of cereals with nitrogen gathering crops, therefore, has been shown to be absolutely essential to the profitable use of commercial fertilizers in any form.

The increase of crop per pound of fertilizing constituents applied has generally been smaller, when barnyard manure was used as the carrier of fertility, than when chemical carriers were used; but the lower cost of barnyard manure has made it possible to use this material with profit when the use of commercial fertilizers resulted in loss.

A marked superiority is indicated from manure which has been kept under cover until required for use, over that which has been exposed, even for but a short time, in an open barnyard, and it seems possible to materially increase the effectiveness of manure by treating it with nitrogen-fixing materials.

Nitrate of soda has shown itself to be the most effective of the carriers of nitrogen employed in these experiments, with sulphate of ammonia, dried blood and linseed oil-meal following in the order named.

Of the four carriers of phosphoric acid used, basic slag and dissolved bone-black show the highest effectiveness, with raw bone meal and acid phosphate not far below.

The tendency to excessive production of straw in wheat and oats is apparently due in part to climatic, and in part to soil conditions, and the remedy apparently lies in systematic rotation, combined with judicious selection and distribution of fertilizing materials.

APPENDIX.

In the tables which follow are given the yields of the crops in the various experiments which have been discussed in the preceding pages. In the great majority of cases these are actual yields; but under some circumstances, as when there has been great lack of uniformity of stand, it has seemed that the actual lesson of the experiment could only be reached by correcting the yields on the basis of the actual stand. The corrected yields are indicated by asterisks.

As shown by the diagrams, or field plans, included in this report, every third plot, beginning with No. 1 in each test, is left continuously unfertilized throughout all the work. In calculating the increase from the fertilizers, it has been assumed that the variations between neighboring unfertilized plots are more likely to be due to gradual than to abrupt changes in the character of the soil, and therefore, instead of taking the simple average of two unfertilized plots, a progressive average has been ascertained, by taking one-third of the difference between the yields of the unfertilized plots and adding this to the smaller yield and subtracting it from the larger yield, to get the probable unfertilized yield of the adjoining plots. To illustrate: If the yield of Plot 1 were 20 bushels and that of Plot 4 were 23 bushels, it would be assumed that Plot 2 should have yielded 21 bushels and Plot 3, 22 bushels, if left unfertilized.

While this method will not always give the actual fact, many trials have shown that the results thus obtained are very much more consistent, taken as a whole, than can be arrived at by taking simple averages. In no case are any but the most general conclusions drawn from the general average of all the unfertilized plots.

TABLE XLIII: YIELDS OF CORN IN 5-YEAR ROTATION—WOOSTER.

Plot	Bushels of ear-corn per acre (1 bu.= 70 lbs.)						Pounds of stover per acre					
	1894	1895	1896	1897	1898	Average	1894	1895	1896	1897	1898	Average
1	17.28	40.57	55.64	18.82	27.07	31.88	1,270	2,640	1,780	1,320	970	1,614
2	17.64	44.21	54.21	24.64	39.43	36.02	1,250	2,560	1,480	1,640	1,180	1,622
3	16.92	39.57	53.89	34.93	29.36	34.93	1,300	2,330	1,610	2,100	1,140	1,696
4	16.17	40.46	47.57	31.54	26.43	32.43	1,170	2,590	1,580	1,820	980	1,628
5	15.50	38.07	54.43	31.57	37.32	35.33	1,120	2,610	1,560	1,780	1,300	1,674
6	19.46	51.07	61.68	40.46	43.93	43.32	1,210	2,600	1,790	2,110	1,380	1,818
7	18.00	39.07	59.64	27.93	26.82	34.29	1,250	2,480	1,620	1,600	990	1,588
8	21.07	41.71	61.43	35.98	40.43	40.11	1,310	2,550	1,860	2,100	1,340	1,832
9	15.92	29.18	57.68	30.32	31.89	33.00	1,110	2,390	1,870	1,840	1,120	1,666
10	17.71	31.07	53.93	24.57	23.36	30.13	1,150	2,050	1,600	1,600	920	1,464
11*	20.46	42.14	68.57	33.89	41.36	41.28	1,350	2,480	1,950	1,900	1,420	1,821
12	24.85	41.04	63.32	37.18	38.96	41.07	1,400	2,390	2,030	2,050	1,250	1,824
13	25.35	32.93	53.71	23.75	21.32	31.41	1,410	2,270	1,700	1,480	960	1,564
14	25.42	38.11	65.36	33.11	42.79	40.96	1,550	2,590	2,170	1,990	1,320	1,924
15	22.17	.....	53.32	22.54	31.00	32.26	1,390	2,600	1,890	1,600	970	1,690
16	21.07	*35.29	49.71	15.36	24.64	27.69	1,400	2,680	1,810	1,240	980	1,622
17	20.50	.....	56.89	31.79	33.93	35.78	1,340	2,770	1,700	2,050	1,150	1,802
18	17.78	.....	58.75	45.96	40.43	40.73	1,350	3,010	1,970	2,700	1,270	2,060
19	21.22	36.86	53.86	25.32	28.32	33.12	1,270	2,780	1,680	1,630	980	1,668
20	17.28	37.21	55.68	44.54	39.86	38.91	1,260	2,650	1,940	2,480	1,320	1,930
21	22.07	36.36	54.86	37.39	37.64	37.66	1,500	2,630	1,950	2,200	1,140	1,884
22	17.17	32.14	44.79	23.57	28.29	29.19	1,170	2,280	1,630	1,650	1,040	1,554
23	16.10	41.07	55.00	37.60	38.64	37.68	1,200	2,600	1,850	2,420	1,200	1,854
24	20.21	37.89	62.00	42.07	40.36	40.51	1,300	2,720	2,200	2,390	1,330	1,988
25	17.35	32.21	50.96	32.36	24.82	31.54	1,100	2,390	1,660	2,200	950	1,660
26	18.32	36.36	59.43	42.86	38.75	39.14	1,320	2,670	2,240	2,550	1,270	2,010
27	15.50	36.71	62.04	41.14	47.64	40.61	1,150	2,510	1,950	2,520	1,600	1,946
28	14.85	33.21	50.16	35.43	44.89	35.71	1,140	2,220	1,850	2,100	1,530	1,768
29	14.96	42.79	62.36	44.68	54.68	43.89	1,100	2,790	2,150	2,590	1,870	2,100
30	14.60	49.36	57.68	40.82	46.18	41.73	1,070	2,680	1,920	2,390	1,400	1,892

TABLE XLIV. YIELDS OF CORN IN 5-YEAR ROTATION — STRONGSVILLE.

Plot	Bushels of ear-corn per acre (1 bu. = 70 lbs.)					Pounds of stover per acre				
	1895	1896	1897	1898	Av'ge	1895	1896	1897	1898	Av'ge
1	37.21	22.50	24.71	32.21	29.16	1,700	1,300	1,450	1,240	1,422
2	38.00	27.21	24.86	31.14	30.30	1,450	1,270	1,630	1,060	1,352
3	36.36	25.79	19.71	21.86	25.93	1,600	1,350	1,240	950	1,285
4	33.21	24.79	15.65	19.50	23.29	1,410	1,420	1,220	950	1,250
5	35.29	28.79	13.00	19.36	24.11	1,520	1,480	1,200	940	1,285
6	41.71	32.29	19.00	25.64	29.66	1,460	1,585	1,240	1,040	1,331
7	36.43	22.64	12.50	19.50	22.77	1,700	1,265	1,450	940	1,339
8	38.00	21.29	22.07	29.79	27.79	1,480	1,100	1,020	1,140	1,185
9	35.21	25.43	17.00	25.36	25.75	1,540	1,225	1,420	1,070	1,314
10	29.43	24.00	23.14	29.79	26.59	1,820	1,140	1,430	1,220	1,402
11	42.79	34.71	36.86	35.43	37.45	1,830	1,430	1,940	1,360	1,640
12	43.36	32.29	33.57	35.71	36.23	1,830	1,530	1,860	1,430	1,662
13	39.29	25.14	25.86	29.14	29.86	1,930	1,190	1,480	1,220	1,455
14	46.79	33.71	27.21	33.71	35.35	2,100	1,440	1,700	1,540	1,695
15	41.14	25.14	16.14	27.79	27.55	1,830	1,265	1,340	1,170	1,401
16	36.29	36.79	18.64	32.29	31.00	2,230	1,715	1,360	1,290	1,649
17	41.71	30.36	26.36	35.57	33.50	2,250	1,615	1,520	1,300	1,671
18	45.07	39.64	25.57	44.43	38.68	2,400	1,800	1,440	1,600	1,810
19	32.50	31.79	21.29	34.07	29.91	2,550	1,565	1,330	1,300	1,686
20	38.50	33.50	32.79	41.07	36.46	2,570	1,575	1,650	1,400	1,799
21	40.14	17.71	33.29	34.79	31.48	2,750	1,150	1,680	1,460	1,760
22	38.14	16.07	26.50	34.36	28.77	3,100	1,060	1,340	1,360	1,715
23	49.57	18.36	28.36	41.00	34.32	2,650	1,120	1,560	1,420	1,687
24	50.14	15.07	32.00	39.21	34.10	2,850	1,110	1,860	1,450	1,817
25	46.43	12.86	24.50	29.07	28.21	2,950	1,040	1,560	1,250	1,700
26	50.21	14.21	24.57	37.50	31.62	3,060	1,190	1,680	1,460	1,847
27	52.07	16.50	27.50	35.21	32.82	2,930	1,180	1,700	1,450	1,815
28	44.57	11.43	14.36	30.36	25.18	2,610	950	1,220	1,350	1,532
29	51.21	19.50	28.86	39.50	34.77	2,490	1,110	1,660	1,470	1,682
30	54.50	24.86	29.00	45.86	38.55	2,630	1,200	1,520	1,460	1,702
31	45.07	16.50	17.57	29.21	27.09	2,500	980	1,380	1,300	1,540
32	.....	18.43	25.36	44.29	29.36	.....	1,135	1,520	1,450	1,368
33	.....	23.00	22.50	45.93	30.48	.....	1,250	1,240	1,640	1,377
34	.....	17.86	14.71	39.36	23.98	.....	1,290	1,350	1,600	1,413
35	.....	29.50	22.36	40.64	30.83	.....	1,625	1,340	1,620	1,528
36	.....	32.57	25.79	51.57	36.64	.....	1,650	1,560	2,070	1,760
37	.....	25.36	19.86	41.93	29.05	.....	1,470	1,360	1,450	1,427
38	.....	26.93	16.00	41.00	27.98	.....	1,490	1,320	1,000	1,470
39	.....	29.21	12.93	33.64	25.26	.....	1,460	1,060	1,450	1,323
40	.....	28.29	19.64	30.86	26.26	.....	1,500	1,360	1,400	1,420

TABLE XLV. YIELDS OF OATS IN 5-YEAR ROTATION — WOOSTER.

Plot	Bushels of grain per acre (1 bu. = 32 lbs.)							Pounds of straw per acre						
	1894	1895	1896	1897	1898	1899	Average	1894	1895	1896	1897	1898	1899	Average
1	23.2	30.62	31.56	42.18	33.44	33.16	32.35	907	1,120	1,410	1,250	1,480	1,000	1,194
2	28.28	34.68	35.39	47.18	42.65	46.25	39.07	1,145	1,240	1,427	1,460	1,435	1,540	1,374
3	24.44	28.36	32.65	44.06	44.06	34.69	34.71	817	992	1,415	1,220	1,990	1,020	1,242
4	26.10	26.40	30.23	40.00	39.68	34.68	32.85	1,165	960	1,632	1,110	1,680	1,050	1,266
5	29.84	26.87	33.91	45.94	40.46	40.46	36.25	1,245	940	1,215	1,430	1,745	1,315	1,315
6	31.25	35.70	42.81	48.44	43.59	52.65	42.41	1,400	1,158	1,780	1,350	2,055	1,745	1,581
7	25.86	26.25	29.92	40.31	37.18	34.53	32.34	1,022	1,010	1,422	1,110	1,540	1,025	1,188
8	30.15	36.17	33.12	48.44	43.44	49.37	40.11	1,335	1,232	1,420	1,480	1,930	1,570	1,494
9	25.15	26.64	25.78	48.75	40.47	37.97	34.13	945	908	1,195	1,510	1,935	1,205	1,283
10	24.14	25.54	21.02	44.37	36.87	36.41	31.39	1,127	933	857	1,180	1,740	1,025	1,144
11	33.28	37.57	37.34	61.56	48.28	58.60	46.10	1,485	1,368	1,725	2,080	2,385	2,035	1,846
12	30.31	40.46	42.42	62.50	49.84	58.12	47.27	1,580	1,555	1,782	2,450	2,395	2,140	1,984
13	21.33	28.91	24.22	41.87	40.15	35.46	31.99	1,067	1,315	1,135	1,360	1,440	1,035	1,225
14	26.02	41.56	31.87	44.37	40.15	43.12	37.85	1,367	1,480	1,580	1,230	1,965	1,390	1,502
15	21.80	30.23	23.91	38.75	36.87	36.25	31.30	1,052	982	985	1,160	1,510	1,040	1,655
16	20.55	28.75	24.84	36.56	35.31	33.44	29.91	1,292	880	1,155	1,050	1,380	950	1,118
17	23.67	37.90	35.00	47.50	46.09	54.69	40.81	1,442	1,215	1,540	1,390	2,175	1,840	1,600
18	20.70	37.03	31.25	36.87	42.50	44.22	38.31	1,037	1,455	1,320	1,040	1,990	1,415	1,444
19	22.27	28.51	26.09	36.87	36.09	34.53	30.73	1,137	988	1,075	890	1,545	1,005	1,107
20	23.98	34.22	26.56	37.50	39.68	44.06	34.33	1,632	1,105	1,060	1,050	1,730	1,410	1,331
21	32.34	29.06	30.31	50.31	45.15	55.78	40.49	1,415	1,070	1,590	1,470	2,255	2,025	1,637
22	28.28	25.78	20.15	37.18	36.09	35.00	30.41	1,145	1,065	935	860	1,845	1,020	1,145
23	32.66	36.09	31.56	52.18	46.56	58.12	42.86	1,505	1,155	1,140	1,700	1,670	2,120	1,548
24	32.81	37.65	36.94	58.12	49.53	59.06	45.68	1,450	1,445	1,617	1,790	2,655	2,200	1,859
25	28.91	28.90	21.41	36.56	37.34	34.37	31.25	1,275	1,075	1,025	1,230	1,855	1,020	1,247
26	35.47	36.48	36.09	56.37	50.31	50.31	44.25	1,365	1,252	1,585	1,730	2,090	1,690	1,619
27	37.50	33.04	37.81	57.50	51.87	61.09	46.47	1,750	1,182	1,620	1,880	2,190	2,175	1,799
28	35.78	25.78	20.94	37.18	38.12	45.62	33.90	1,505	755	900	1,090	1,780	1,520	1,258
29	39.22	31.40	41.09	49.67	51.09	59.37	45.31	1,895	955	1,865	1,410	2,225	2,100	1,748
30	37.19	32.65	37.19	33.43	36.87	56.87	39.03	1,560	1,125	1,690	780	1,560	1,990	1,451

TABLE XLVI. YIELDS OF OATS IN 5-YEAR ROTATION — STRONGSVILLE.

Plot	Bushels of grain per acre (1 bu. = 32 lbs.)					Pounds of straw per acre				
	1896	1897	1898	1899	Av'ge	1896	1897	1898	1899	Av'ge
1	26.17	30.31	41.09	33.59	32.79	1,337	890	1,845	1,295	1,342
2	30.23	40.62	51.25	45.78	41.97	1,732	1,240	2,080	1,535	1,647
3	23.36	34.37	44.84	32.50	33.77	1,472	940	1,765	860	1,259
4	23.67	34.22	37.42	30.31	31.40	1,432	965	1,332	800	1,132
5	23.44	34.06	36.25	33.12	31.72	1,745	970	1,310	940	1,242
6	35.94	45.62	50.86	47.34	44.94	1,815	1,320	1,832	1,455	1,605
7	28.52	32.97	34.53	31.17	31.80	1,567	925	1,105	832	1,107
8	31.09	41.56	50.00	51.41	43.51	1,730	1,230	1,870	1,595	1,606
9	26.09	31.56	42.81	44.45	36.23	2,035	890	1,460	1,477	1,465
10	20.70	30.00	47.65	44.69	35.76	1,287	960	1,715	1,470	1,358
11	33.12	42.50	64.06	53.98	48.41	19.35	1,480	2,800	1,722	1,984
12	34.22	43.33	65.47	56.72	49.93	2,010	1,630	2,635	1,985	2,065
13	25.23	35.47	49.84	38.44	37.24	1,782	1,085	2,085	1,250	1,550
14	31.33	38.44	52.19	41.64	40.90	1,872	1,230	2,050	1,267	1,605
15	27.81	31.72	41.33	36.25	34.28	1,615	1,025	1,427	1,140	1,302
16	22.58	36.22	43.75	35.00	34.39	1,337	1,120	1,570	1,000	1,257
17	31.64	34.53	59.06	54.14	44.84	1,912	1,135	2,560	1,687	1,823
18	28.20	38.28	49.06	41.25	39.20	1,487	1,285	1,810	1,260	1,460
19	18.12	33.12	44.53	35.46	32.81	1,300	980	1,425	1,115	1,205
20	25.78	30.31	52.58	41.72	37.60	1,570	1,130	1,997	1,315	1,503
21	27.87	39.69	60.70	58.36	46.65	2,087	1,270	2,907	2,082	2,086
22	28.28	33.12	51.01	38.59	37.75	1,755	940	2,337	1,345	1,594
23	32.50	44.38	64.84	56.25	49.49	2,770	1,420	3,275	1,950	2,353
24	35.69	43.60	63.91	52.66	48.96	28.47	1,405	2,885	1,835	2,243
25	29.38	28.28	45.78	32.81	34.06	2,270	795	1,945	1,100	1,527
26	41.25	40.31	58.44	50.23	47.56	2,525	1,210	2,220	1,572	1,982
27	37.03	43.75	58.20	46.87	46.46	2,640	1,340	2,237	1,470	1,922
28	29.84	28.44	36.84	33.75	32.22	1,840	890	1,061	920	1,178
29	39.53	38.91	56.17	47.50	45.53	2,260	1,255	2,202	1,430	1,787
30	35.94	34.84	45.31	53.36	42.36	2,300	1,065	1,480	1,722	1,642
31	25.16	24.84	39.30	31.17	30.12	1,800	805	1,422	982	1,252
32	37.19	33.44	53.75	47.19	42.89	2,515	1,030	1,900	1,530	1,744
33	37.73	35.31	48.98	46.80	42.20	2,567	1,150	1,972	1,632	1,830
34	24.84	25.62	37.11	33.05	30.15	1,755	800	1,192	1,142	1,222
35	36.80	37.66	51.95	47.50	43.48	2,392	1,275	2,087	1,680	1,858
36	36.87	37.66	51.80	46.09	43.10	2,315	1,235	1,822	1,625	1,749
37	21.33	27.81	38.12	33.67	30.23	1,672	830	1,390	1,182	1,268
38	27.73	30.94	35.78	30.36	31.20	2,363	810	1,085	1,027	1,321
39	33.67	30.62	33.36	28.12	31.44	1,882	840	1,112	930	1,191
40	22.97	29.22	39.69	26.25	29.53	1,815	885	1,270	730	1,175

TABLE XLVII: YIELDS OF WHEAT IN 5-YEAR ROTATION — WOOSTER.

Plot	Bushels of grain per acre (1 bu.=60 lbs.)							Pounds of straw per acre						
	1894	1895	1896	1897	1898	1899	Average	1894	1895	1896	1897	1898	1899	Average
1	13.54	1.42	0.87	14.25	13.87	4.42	8.06	1,437	115	127	1,645	1,397	635	893
2	13.62	6.50	4.00	20.58	17.04	11.42	12.19	2,382	310	530	2,235	1,627	1,215	1,383
3	24.92	1.17	1.67	14.67	13.87	8.50	10.80	2,805	230	230	1,500	1,367	1,090	1,204
4	22.17	2.58	0.96	12.17	12.29	7.67	9.64	2,620	285	162	1,240	1,112	1,140	1,093
5	20.54	3.83	1.37	17.00	15.12	9.00	11.14	2,517	440	277	1,900	1,502	1,210	1,308
6	16.71	9.50	4.92	27.83	25.25	17.67	16.98	2,847	710	655	3,490	2,335	1,890	1,988
7	20.95	2.08	0.75	12.17	14.16	5.83	9.32	2,642	175	95	1,290	1,450	810	1,077
8	18.87	9.42	6.50	20.42	20.79	15.08	15.18	2,467	685	670	2,258	1,722	1,535	1,555
9	22.54	3.17	2.37	14.17	18.21	8.50	11.49	2,497	260	260	1,400	1,927	1,230	1,262
10	18.04	3.17	1.21	9.83	17.21	5.33	9.13	1,967	210	277	1,010	1,647	770	980
11	18.54	10.83	9.04	30.58	33.67	22.83	20.91	3,087	860	1,057	3,665	3,110	2,580	2,393
12	20.29	11.83	6.37	34.33	31.92	24.67	21.57	3,382	880	717	4,150	3,035	2,820	2,497
13	20.79	2.67	1.42	9.83	13.46	6.25	9.07	2,352	190	265	1,050	1,292	725	979
14	18.79	7.33	8.08	28.83	27.50	19.42	18.32	3,322	660	975	3,420	2,500	2,235	2,185
15	18.37	7.83	4.00	27.92	25.75	18.67	17.09	3,047	580	510	3,125	2,455	2,040	1,959
16	19.04	2.08	1.41	9.33	9.54	5.17	7.76	2,207	225	215	960	777	630	836
17	21.04	8.83	6.04	17.33	15.96	14.67	13.98	2,887	640	767	2,080	1,402	1,650	1,563
18	16.96	6.42	7.00	17.41	15.46	15.83	13.18	2,882	745	1,030	1,925	1,312	1,960	1,642
19	18.21	2.83	1.45	9.00	10.04	7.08	8.10	1,957	280	212	840	927	835	842
20	17.46	7.17	4.79	12.92	15.04	13.50	11.81	2,752	670	612	1,495	1,267	1,570	1,394
21	20.37	8.75	8.54	28.33	25.75	22.75	19.08	3,377	775	937	3,320	2,185	2,705	2,216
22	17.54	2.17	0.75	8.00	11.87	9.08	8.23	1,997	220	255	730	1,087	1,005	882
23	19.04	10.92	6.58	21.42	25.92	20.17	17.34	3,057	895	665	2,265	2,185	2,490	1,926
24	21.54	11.92	6.70	23.42	25.67	21.17	18.40	3,407	535	847	2,675	2,120	2,630	2,036
25	22.21	3.58	1.16	9.83	12.12	9.25	9.69	2,517	335	160	910	1,072	1,105	1,016
26	18.54	11.17	6.16	26.17	28.83	20.17	18.51	3,187	880	920	2,870	2,570	2,280	2,118
27	15.62	17.58	5.16	28.00	27.92	22.92	19.53	3,112	1,545	590	2,930	2,425	2,575	2,196
28	20.37	7.25	0.66	9.92	11.71	8.50	9.73	2,277	715	70	865	1,047	990	994
29	18.29	15.58	6.58	28.83	24.25	21.50	19.17	3,152	1,315	665	3,300	2,045	2,390	2,144
30	15.79	17.00	4.62	18.92	16.96	17.42	15.12	2,752	1,130	702	1,985	1,332	1,825	1,621

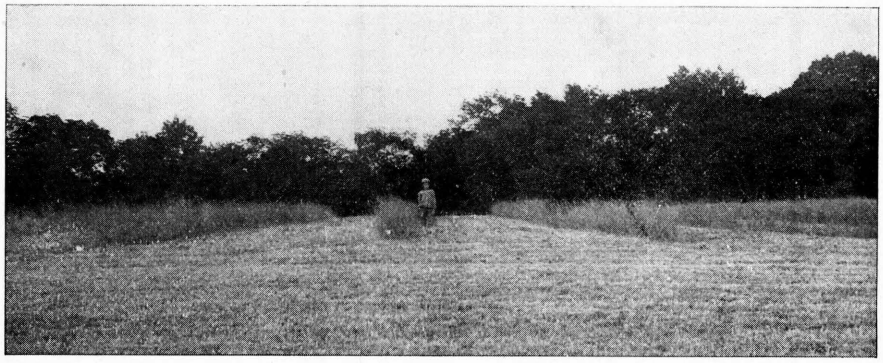
TABLE XLVIII: YIELDS OF WHEAT IN 5-YEAR ROTATION — STRONGSVILLE.

Plot	Bushels of grain per acre (1 bu. = 60 lbs.)				Pounds of straw per acre			
	1897	1898	1899	Av'ge	1897	1898	1899	Av'ge
1	10.33	1.67	5.17	5.72	860	170	490	507
2	24.93	7.46	8.67	13.69	3,090	683	920	1,564
3	13.08	1.71	3.25	6.01	1,215	213	165	531
4	16.50	1.67	3.17	7.11	1,590	250	290	710
5	15.17	2.54	2.08	6.60	1,410	308	195	638
6	30.17	13.00	11.00	18.06	3,490	1,220	920	1,877
7	16.50	1.42	2.17	6.70	1,630	165	150	648
8	23.08	11.67	8.92	14.56	2,555	1,100	635	1,430
9	20.00	3.12	3.75	8.96	2,160	343	375	959
10	13.92	2.08	3.83	6.61	1,425	255	380	687
11	25.67	15.67	15.92	19.09	2,660	1,530	1,295	1,828
12	33.67	16.12	20.83	23.54	3,930	1,633	2,050	2,538
13	12.83	2.25	6.17	7.08	1,190	275	600	688
14	29.33	16.50	17.33	21.05	3,220	1,470	1,620	2,103
15	27.00	14.08	14.75	18.61	2,880	1,165	1,345	1,797
16	15.67	2.67	5.00	7.78	1,480	330	300	703
17	16.17	9.67	12.25	12.70	1,510	940	1,145	1,198
18	27.67	15.17	10.25	17.70	2,980	1,350	955	1,762
19	8.83	2.00	4.00	4.94	770	180	210	387
20	20.00	9.17	10.42	13.20	1,900	910	915	1,242
21	18.04	12.83	17.33	16.07	1,737	1,080	2,060	1,626
22	15.08	1.50	8.00	8.19	1,495	180	700	792
23	24.50	11.75	17.92	18.06	2,450	995	2,190	1,878
24	28.67	10.00	17.08	18.58	2,900	790	2,185	1,958
25	14.04	1.58	6.00	7.21	1,357	205	625	729
26	29.58	13.42	17.67	20.22	3,005	1,145	1,965	2,038
27	23.50	12.25	15.67	17.14	2,310	1,055	1,650	1,672
28	18.58	*1.88	2.83	7.76	1,745	228	255	743
29	32.00	17.83	15.50	21.78	3,400	1,440	1,635	2,158
30	29.58	13.67	9.92	17.72	3,265	1,140	950	1,785
31	13.12	1.92	2.67	5.90	1,212	215	285	571
32	27.75	12.00	13.00	17.58	2,935	1,000	1,300	1,745
33	22.75	11.08	11.14	14.99	2,315	855	635	1,268
34	16.37	1.37	2.50	6.75	1,597	178	250	675
35	28.83	11.62	13.83	18.09	2,870	1,023	1,390	1,761
36	32.00	10.33	14.00	18.78	3,380	960	1,385	1,908
37	15.83	0.71	3.00	6.51	1,370	86	295	584
38	27.83	11.08	11.25	16.72	2,870	945	1,310	1,708
39	24.33	7.37	5.92	12.54	2,260	658	565	1,161
40	16.50	1.00	3.33	6.94	1,470	121	280	624

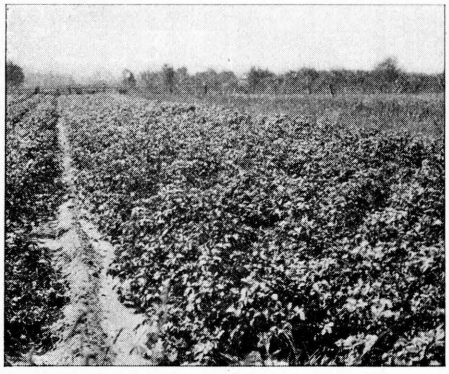
TABLE XLIX: YIELDS OF HAY IN 5-YEAR ROTATION — WOOSTER.

Pounds per acre

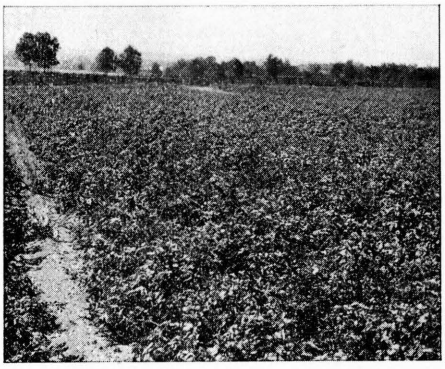
Plot	First-year crops, (clover)					Second-year crops, (timothy)				
	1895	1896	1897	1898	Average	1896	1897	1898	1899	Average
1	1,300	1,370	1,660	1,180	1,377	3,800	2,710	1,150	2,500	2,540
2	1,300	2,360	2,730	1,490	1,970	3,000	3,290	1,500	2,460	2,562
3	1,820	1,600	1,910	1,610	1,735	4,550	3,240	1,250	2,040	2,770
4	1,860	1,700	1,890	1,640	1,772	4,050	2,760	900	1,940	2,412
5	1,360	2,460	2,320	1,230	1,842	3,500	3,520	1,330	2,340	2,672
6	1,300	3,320	3,930	2,550	2,775	3,380	4,100	1,770	2,560	2,952
7	1,100	1,450	2,060	2,100	1,677	3,650	2,590	1,050	1,900	2,297
8	1,280	2,350	3,960	2,300	2,472	4,030	3,000	1,200	2,020	2,562
9	1,600	1,960	2,560	1,970	2,022	4,050	2,710	1,150	1,700	2,402
10	1,260	1,350	2,090	1,880	1,645	3,700	2,610	650	1,520	2,120
11	1,100	3,050	4,350	2,460	2,740	3,450	3,580	1,800	2,800	2,907
12	1,440	3,450	4,270	2,600	2,940	3,000	2,800	1,900	2,760	2,615
13	1,280	1,210	2,510	2,320	1,830	3,920	2,280	850	1,740	2,197
14	1,380	2,820	4,310	2,750	2,815	3,520	3,520	1,400	2,720	2,790
15	1,420	1,980	3,390	2,320	2,277	3,570	2,550	1,350	2,660	2,532
16	1,120	1,140	2,060	2,120	1,610	3,750	2,420	950	2,000	2,280
17	1,280	2,770	3,660	2,650	2,590	4,000	2,850	1,550	2,340	2,685
18	1,640	3,870	4,660	2,350	3,130	4,950	3,600	2,350	3,000	3,475
19	1,020	1,650	2,540	1,910	1,780	3,710	2,600	1,010	2,340	2,415
20	1,400	3,400	3,310	2,090	2,550	4,650	3,900	1,570	2,040	3,040
21	1,280	2,560	4,060	2,170	2,517	4,150	2,950	1,050	2,100	2,562
22	1,380	1,050	1,940	1,630	1,500	3,840	2,250	550	1,400	2,010
23	1,160	2,750	4,100	2,030	2,510	4,100	3,200	1,050	1,820	2,542
24	1,140	2,700	3,590	2,250	2,420	4,030	3,300	850	1,740	2,480
25	1,260	1,580	2,030	1,900	1,692	4,350	2,800	740	1,540	2,357
26	1,180	4,000	3,600	1,800	2,645	4,100	4,600	1,400	2,340	3,110
27	1,120	3,650	2,740	1,900	2,350	3,930	4,650	1,380	2,280	3,060
28	1,460	2,400	1,300	1,600	1,690	4,380	4,520	670	1,260	2,707
29	1,240	3,760	3,390	1,750	2,535	4,200	5,050	2,120	3,260	3,657
30	1,100	3,400	3,230	2,150	2,470	4,540	5,100	1,750	3,000	3,597



"In harvesting the hay the mowing machine is driven to stakes * * * the grass growing in the dividing spaces being left until the hay on the plots is cured, weighed and hauled away."

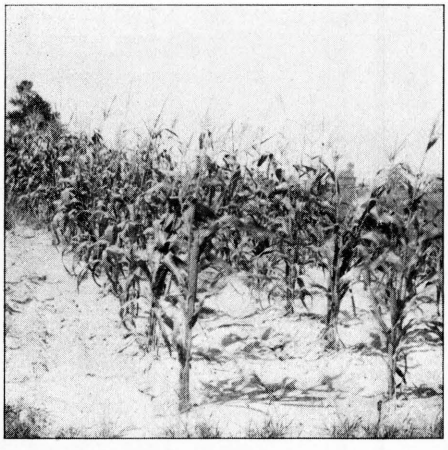


Plot 10, unfertilized.

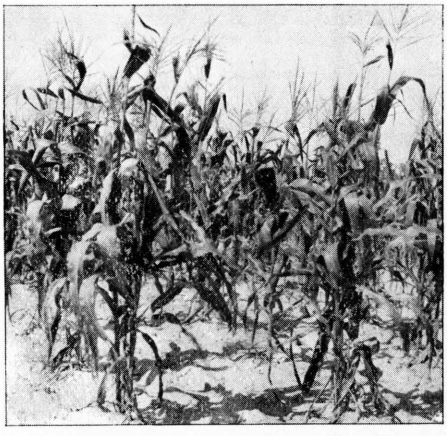


Plot 11, complete fertilizer.

POTATOES IN 3-YEAR ROTATION, WOOSTER.



Plot 1, unfertilized.



Plot 2, complete fertilizer.

CORN IN CONTINUOUS CULTURE, WOOSTER.

TABLE I. YIELDS OF HAY IN ROTATIONS AT STRONGSVILLE

Pounds of hay per acre

Plot	5-year rotation					3-year rotation
	1st-year crop (clover)				2d year crop	
	1897	1898	1899	Average	1898	1897
1	1,550	1,400	760	1,237	2,260	1,560
2	2,070	2,040	2,220	2,110	1,560	1,760
3	1,560	1,080	1,060	1,233	1,480	1,120
4	1,010	1,340	1,020	1,123	1,440	1,060
5	1,340	2,040	1,500	1,627	1,400	2,000
6	2,040	2,260	2,540	2,280	1,450	1,160
7	2,180	2,380	1,200	1,920	2,060	1,280
8	2,180	2,440	2,680	2,433	1,880	1,640
9	1,840	2,100	1,560	1,833	1,800	960
10	1,500	1,600	1,200	1,433	1,680	820
11	2,050	2,420	2,300	2,257	1,500	2,260
12	1,580	2,140	2,400	2,040	1,880	1,620
13	1,590	1,580	1,340	1,503	1,640	1,080
14	3,080	2,080	2,300	2,487	2,160	1,960
15	2,250	2,080	2,160	2,163	1,840	2,580
16	1,610	1,420	1,780	1,603	1,900	1,140
17	2,200	2,420	2,200	2,280	1,840	1,120
18	2,100	2,520	2,780	2,467	1,680	1,520
19	1,270	1,340	1,560	1,390	1,440	900
20	1,620	2,280	2,520	2,140	1,420	1,380
21	1,960	2,260	2,800	2,340	1,380	1,580
22	1,540	1,820	1,900	1,753	1,480	1,260
23	2,350	2,320	3,800	2,823	1,840	1,980
24	1,980	2,100	3,820	2,633	1,740	1,600
25	1,500	2,220	1,520	1,747	1,160	960
26	1,910	2,660	3,740	2,770	1,740	1,760
27	1,820	2,520	2,580	2,307	1,800	1,420
28	1,560	2,200	1,340	1,700	1,860	*1,140
29	2,120	3,180	2,600	2,633	2,340	2,040
30	2,500	3,100	2,780	2,793	2,600	1,300
31	1,380	2,080	1,280	1,580	1,940	960
32	2,260	2,880	2,360	2,500	2,340	1,680
33	2,160	2,960	2,700	2,607	2,200	1,660
34	1,130	1,400	1,200	1,243	1,540	1,020
35	1,750	1,980	2,780	2,170	1,640	1,760
36	1,880	2,700	2,680	2,420	1,540	1,200
37	*1,130	1,460	1,580	1,390	1,300	.....
38	2,120	2,400	2,780	2,433	1,800	.....
39	1,220	2,400	2,460	2,027	1,300	.....
40	1,130	1,480	1,440	1,350	1,320	.....

TABLE LI: YIELDS OF CLOVER IN ROTATION WITH WHEAT AND POTATOES — WOOSTER.

Plot	Pounds of hay per acre				
	1896	1897	1898	1899	Av'age
1	5,250	5,350	3,300	2,896	4,199
2	5,000	4,750	4,150	3,088	4,247
3	4,150	4,750	3,950	2,796	3,911
4	4,400	4,500	3,900	2,632	3,858
5	5,000	4,700	3,700	2,935	4,048
6	5,430	4,420	3,500	3,896	4,311
7	5,000	4,180	3,350	3,232	3,940
8	4,850	4,250	3,400	4,059	4,140
9	5,030	4,450	3,680	4,030	4,297
10	4,750	4,320	3,860	2,560	3,872
11	4,450	4,430	3,490	3,650	4,005
12	5,000	4,790	3,500	4,117	4,352
13	4,200	4,430	3,730	3,136	3,874
14	4,350	4,620	3,680	4,132	4,195
15	4,880	4,350	3,520	4,000	4,187
16	3,430	4,600	3,520	2,528	3,519
17	4,660	4,550	3,380	3,183	3,943
18	4,950	5,120	3,620	3,694	4,346
19	3,450	3,900	3,480	2,512	3,335
20	4,600	4,430	3,730	3,694	4,113
21	4,200	3,750	3,140	4,132	3,805
22	3,450	3,920	3,100	3,264	3,433
23	3,380	3,800	3,300	3,402	3,470
24	3,450	4,440	3,300	2,905	3,524
25	2,800	4,820	3,160	2,496	3,319
26	3,050	4,390	3,600	3,110	3,537
27	3,480	4,210	3,380	3,051	3,530
28	3,200	4,470	3,280	2,448	3,349
29	4,650	4,460	3,420	4,263	4,198
30	4,600	3,880	3,350	3,854	3,923
31	2,820	4,240	3,400	2,144	3,151
32	.....	4,730	3,700	3,694	3,697
33	.....	4,620	3,800	2,394	3,097
34	.....	4,320	3,550	1,984	2,767

TABLE LII: YIELDS OF POTATOES IN 3-YEAR ROTATION — WOOSTER.

Plot	Bushels per acre (1 bu.=60 lbs.)						
	1894	1895*	1896*	1897	1898	1899*	Average
1	72.00	175.69	161.96	209.6	158.58	191.34	161.53
2	102.91	206.04	200.20	210.6	167.83	207.00	182.42
3	98.34	165.75	202.90	208.9	171.33	207.23	174.91
4	100.83	159.52	206.00	182.7	158.58	202.99	168.44
5	108.67	143.30	235.83	192.7	155.18	202.63	173.05
6	128.34	172.02	259.09	227.0	161.79	215.96	194.02
7	112.17	120.00	204.00	190.5	144.00	201.48	162.03
8	138.67	162.16	218.28	218.2	169.58	222.71	188.26
9	122.34	142.36	221.00	216.2	165.25	210.24	179.56
10	99.83	121.36	216.44	191.7	151.75	202.32	163.89
11	124.17	158.35	228.48	219.2	160.58	201.90	182.11
12	122.33	199.08	226.44	221.3	167.46	200.52	189.51
13	95.10	122.40	214.20	174.8	138.46	202.14	157.85
14	142.05	185.84	251.00	216.8	159.83	210.37	194.32
15	149.50	202.64	240.72	233.3	143.29	214.43	197.32
16	79.67	141.48	209.10	166.6	134.04	210.59	156.90
17	85.50	131.72	184.00	177.3	156.75	209.90	157.52
18	93.50	121.52	177.88	178.6	165.25	210.70	157.91
19	101.50	118.72	176.44	167.1	147.25	201.13	152.03
20	142.22	168.09	218.88	216.3	168.71	208.52	187.12
21	150.05	153.60	208.08	217.8	150.00	209.92	181.57
22	118.33	114.24	187.88	178.0	134.12	203.29	155.98
23	150.33	170.13	218.28	218.0	155.79	200.53	185.51
24	151.50	164.00	189.72	203.0	159.17	198.85	177.71
25	112.33	102.20	178.00	175.3	147.04	182.85	149.62
26	136.50	127.28	.....	198.7	155.92	192.78	*164.88
27	132.67	138.72	213.04	206.5	163.62	194.41	174.83
28	104.83	100.96	198.88	184.5	151.96	186.41	154.59
29	138.50	111.76	198.86	213.8	171.79	198.50	172.20
30	125.33	133.80	255.00	238.5	166.21	206.91	187.62
31	112.17	88.72	185.00	186.5	150.71	173.76	149.48
32	.....	80.96	174.80	174.2	174.17	202.50	.....
33	.....	.....	197.86	164.0	151.33	198.19	.....
34	.....	.....	186.00	148.3	143.54	183.53	.....

TABLE LIII: YIELDS OF WHEAT IN ROTATION WITH POTATOES AND CLOVER — WOOSTER.

Plot	Bushels of grain per acre (1 bu. = 60 lbs.)						Pounds of straw per acre					
	1895	1896	1897	1898	1899	Av'ge	1895	1896	1897	1898	1899	Av'ge
1	8.67	16.67	33.67	23.54	27.83	22.08	780	1,340	3,530	2,407	3,630	2,337
2	15.92	17.83	35.25	26.58	29.75	25.07	1,195	1,780	3,685	2,555	3,565	2,556
3	9.17	11.50	38.00	24.08	31.00	22.75	700	1,030	3,380	2,775	2,790	2,135
4	7.83	6.58	35.50	20.37	29.00	19.86	880	535	3,570	2,017	2,960	1,992
5	10.17	8.79	38.50	23.21	30.50	22.23	890	972	4,210	2,607	3,170	2,370
6	18.58	10.58	39.25	34.92	34.67	27.60	1,335	915	4,245	3,655	3,620	2,754
7	8.91	5.33	34.17	25.25	26.75	20.08	865	480	3,340	2,505	2,875	2,013
8	20.17	10.29	39.83	34.25	34.33	27.77	1,440	872	3,780	2,925	3,580	2,519
9	12.00	11.75	45.67	32.42	33.92	27.15	930	1,005	4,160	3,015	3,215	2,465
10	8.33	6.87	36.17	23.37	29.50	20.85	800	667	3,710	1,957	2,890	2,005
11	16.25	15.20	45.00	33.25	39.00	29.74	1,225	1,187	4,400	3,135	4,040	2,797
12	19.75	13.54	48.00	35.08	39.25	31.12	1,665	1,217	4,820	3,135	4,295	3,026
13	8.00	7.45	37.33	24.92	28.75	21.29	670	712	3,810	2,105	2,925	2,044
14	18.17	18.50	47.75	37.25	38.67	32.07	1,360	1,340	4,635	3,815	4,110	3,052
15	18.67	14.33	44.00	37.42	35.67	30.02	1,280	1,040	4,210	3,405	4,000	2,787
16	7.75	7.21	37.50	23.08	27.33	20.57	685	577	3,700	2,325	2,790	2,015
17	8.92	10.25	37.83	25.58	30.83	22.68	715	865	3,730	2,545	3,220	2,215
18	9.75	11.83	34.33	27.92	33.08	23.38	765	960	3,290	2,645	3,585	2,249
19	6.08	6.16	32.92	20.21	25.83	18.24	685	410	3,215	2,037	2,520	1,773
20	9.00	9.12	33.58	30.08	34.08	23.17	660	762	3,045	3,045	3,595	2,221
21	16.67	10.62	36.83	31.75	35.50	26.27	1,250	852	3,390	2,695	3,850	2,407
22	7.50	4.79	31.17	22.71	22.00	17.63	700	452	2,980	2,187	2,040	1,672
23	16.67	8.83	35.50	35.92	36.00	26.58	1,100	820	3,330	3,195	4,140	2,517
24	16.50	9.16	38.67	34.92	35.17	26.88	960	660	3,730	3,155	4,010	2,503
25	6.67	6.91	32.50	20.87	23.17	18.02	550	685	3,100	1,897	2,290	1,704
26	14.25	10.29	43.92	35.58	37.25	28.26	1,045	1,082	4,465	3,465	3,965	2,804
27	14.50	12.41	43.42	36.58	36.67	28.72	880	1,085	4,415	3,455	4,020	2,771
28	7.00	6.25	34.50	24.92	23.00	19.13	830	745	3,130	2,455	2,370	1,906
29	17.92	11.87	41.17	38.25	39.50	29.74	1,275	1,187	4,080	3,875	4,330	2,939
30	9.92	5.66	34.67	35.08	30.50	23.17	805	580	3,170	3,175	3,120	2,170
31	5.92	*6.00	33.67	24.58	24.25	18.88	545	*600	3,130	2,375	2,495	1,829
32	.....	.....	39.17	32.25	34.58	35.33	.....	.....	3,470	2,865	3,845	3,393
33	.....	.....	39.17	32.92	35.83	35.97	.....	.....	3,550	2,775	3,900	3,408
34	.....	.....	30.83	22.04	23.17	25.35	.....	.....	2,850	1,977	2,410	2,412

TABLE LIV. YIELDS OF WHEAT IN ROTATION WITH POTATOES AND CLOVER — STRONGSVILLE.

Plot	Bushels of grain per acre (1 bu. = 60 lbs.)				Pounds of straw per acre			
	1897	1898	1899	Av'ge	1897	1898	1899	Av'ge
1	26.42	*2.10	12.17	13.56	2,235	*233	1,270	1,253
2	31.50	11.08	19.50	20.69	3,310	1,045	1,870	2,075
3	32.33	1.75	10.83	14.97	2,660	205	1,070	1,312
4	19.33	1.64	*7.55	9.51	1,520	182	*705	802
5	19.83	0.67	13.50	11.33	2,010	60	1,270	1,113
6	34.50	10.00	30.83	25.11	3,130	944	2,680	2,251
7	20.58	0.47	9.00	10.02	1,725	52	820	866
8	34.58	8.25	28.83	23.89	3,205	710	2,390	2,102
9	22.33	1.85	11.33	11.84	1,860	170	1,180	1,070
10	17.17	1.23	8.00	8.80	1,570	136	760	822
11	39.33	8.75	30.83	36.30	3,640	605	3,110	2,452
12	41.67	10.08	26.00	25.92	4,067	990	2,380	2,479
13	18.33	0.94	8.83	9.37	1,700	104	850	885
14	42.67	11.50	27.67	27.28	4,280	1,000	2,380	2,553
15	31.83	6.50	31.00	23.11	2,770	590	3,080	2,147
16	16.25	1.34	6.67	8.09	1,545	149	700	798
17	20.33	4.50	13.00	12.61	1,700	370	1,160	1,077
18	28.68	10.17	12.33	17.06	2,598	1,050	1,060	1,569
19	20.83	2.46	5.33	9.54	2,070	273	600	981
20	26.33	5.08	10.00	13.80	2,340	475	680	1,165
21	39.50	5.92	26.50	23.97	3,430	625	2,210	2,088
22	20.00	3.01	6.67	9.89	1,850	334	600	928
23	34.00	7.67	27.33	23.00	3,000	640	2,420	2,020
24	35.84	10.58	18.67	21.70	3,850	800	1,580	2,077
25	19.75	0.47	8.00	9.41	1,855	52	600	836
26	39.79	12.08	29.50	27.12	3,912	1,115	2,550	2,526
27	36.83	8.50	23.33	22.89	3,396	750	2,080	2,075
28	21.07	1.72	5.50	9.43	2,061	193	390	881
29	40.75	18.33	27.50	28.86	3,855	1,410	2,350	2,538
30	19.33	6.42	12.33	12.69	2,675	475	1,040	1,397
31	20.67	5.32	7.50	11.16	1,680	591	650	974
32	31.80	16.67	26.67	25.05	2,887	1,430	2,340	2,219
33	34.17	18.75	27.33	26.75	2,990	1,525	2,640	2,365
34	20.77	3.74	5.33	9.95	1,915	416	520	950
35	39.83	13.75	28.33	27.30	3,810	1,195	3,040	2,682
36	34.95	22.33	24.08	27.12	3,860	1,860	2,215	2,645
37	16.50	2.87	7.55	8.97	1,410	316	705	810
38	17.35	10.50	.....	13.92	1,755	1,000	.....	1,377

TABLE LV: YIELDS OF CORN IN CONTINUOUS CULTURE — COLUMBUS.

Plot	Bushels of ear-corn per acre. (1 bu.= 70 lbs.)											
	1888*	1889*	1890*	1891	1892	1893	1894	1895	1896	1897	1898	Aver-age
1	86.0	64.6	51.3	59.4	66.3	35.6	38.60	16.27	44.93	31.57	23.79	46.85
2	83.0	65.0	49.4	61.1	61.4	38.3	46.35	20.32	49.86	34.43	18.07	47.93
3	89.4	60.0	50.3	61.7	65.7	40.7	52.39	22.98	52.50	39.71	34.00	51.76
4	94.2	68.3	51.6	58.3	63.3	38.2	48.57	25.68	52.29	38.00	20.71	50.83
5	91.4	67.7	50.4	63.1	74.9	37.6	49.57	27.62	53.79	48.57	32.00	54.70
6	96.8	68.9	50.3	69.75	73.57	38.86	49.25	28.65	47.57	50.29	23.43	54.31
7	93.0	59.3	44.1	58.2	64.7	37.0	47.07	28.13	49.36	39.86	20.43	49.20
8	89.5	63.7	48.4	54.2	74.0	40.0	51.60	30.48	58.57	40.86	25.71	52.46
9	93.1	67.6	53.9	68.0	76.4	40.7	53.89	29.56	54.71	41.43	26.29	55.05
10	92.1	61.1	47.4	59.4	66.0	38.3	47.10	24.60	45.57	37.29	18.86	48.88
11	85.7	71.1	50.5	69.5	76.0	41.25	51.46	30.55	56.43	43.00	29.00	54.95
12	93.7	63.9	54.1	71.6	77.4	40.2	50.78	26.43	61.00	40.71	28.29	55.28
13	90.5	67.7	48.1	59.7	68.3	42.4	44.64	24.68	48.50	33.43	16.00	49.45
14	89.2	61.4	50.3	68.2	79.9	40.2	48.89	21.82	52.00	34.71	25.93	52.05
15	88.0	57.4	45.7	65.6	69.6	42.0	46.17	25.99	53.36	39.43	31.00	51.30
16	87.4	56.7	43.6	50.4	61.4	37.0	40.17	19.92	42.71	31.86	15.86	44.27
17	89.2	57.3	47.8	67.1	76.1	40.4	48.14	21.78	53.43	37.86	23.43	51.14
18	89.4	61.0	47.5	63.2	75.0	38.2	44.25	19.09	55.00	44.57	22.43	50.88
19	78.6	55.4	39.9	52.3	64.9	38.7	34.21	16.82	47.00	30.71	15.71	43.11
20	93.9	66.4	45.1	62.7	70.3	39.8	40.60	19.13	47.86	44.43	27.71	50.72
21	105.2	72.6	46.2	70.2	73.7	42.4	45.89	18.61	47.14	35.14	30.57	53.42
22	100.0	61.3	47.0	63.4	68.6	41.7	41.68	14.40	43.71	30.86	20.14	48.44

TABLE LV: YIELDS OF CORN IN CONTINUOUS CULTURE — COLUMBUS — Continued.

Plot	Pounds of stover per acre											
	1888*	1889*	1890*	1891	1892	1893	1894	1895	1896	1897	1898	Average
1	7,600	3,472	2,436	3,640	3,420	2,050	1,550	1,111	2,200	1,500	1,200	2,744
2	6,195	3,276	2,514	3,520	3,390	2,225	2,050	1,833	2,000	1,500	850	2,668
3	7,255	3,390	3,246	3,800	4,500	2,530	2,550	1,889	2,650	1,700	1,000	3,142
4	6,195	3,564	2,503	3,500	4,070	2,225	1,950	1,778	2,250	1,650	650	2,758
5	8,256	3,788	2,932	4,260	4,950	2,475	2,550	1,778	2,650	2,100	2,050	3,344
6	7,171	3,604	2,790	4,350	5,300	2,550	2,150	2,611	2,200	2,000	1,100	3,257
7	6,689	3,441	2,480	3,570	4,100	2,225	1,850	1,833	2,100	1,800	900	2,817
8	6,661	3,762	2,780	3,930	4,720	2,550	2,450	2,167	3,200	2,500	1,100	3,256
9	7,805	4,101	3,040	4,020	5,210	2,610	2,200	1,944	1,800	2,800	1,000	3,321
10	7,271	3,774	2,280	3,410	3,850	2,240	1,900	1,556	2,300	1,500	900	2,816
11	6,959	3,488	2,966	4,190	4,930	2,750	2,650	2,111	2,650	2,500	1,300	3,318
12	6,456	4,028	2,857	4,200	5,350	2,900	2,500	2,056	2,450	1,700	1,300	3,254
13	7,260	3,675	2,465	3,670	3,930	2,300	2,100	1,344	2,200	1,500	800	2,840
14	7,087	3,660	3,141	4,040	5,400	2,800	2,200	1,833	2,980	2,000	1,000	3,286
15	7,475	3,270	3,276	[1]	4,850	2,500	2,500	2,056	2,320	3,000	1,100	3,235
16	5,606	2,743	2,352	2,980	3,330	2,050	1,700	1,778	2,080	1,500	700	2,438
17	7,235	3,780	2,781	3,900	4,660	2,275	2,500	1,889	2,650	1,700	1,000	3,125
18	6,670	3,392	2,903	3,720	4,700	2,525	1,800	1,722	2,550	2,450	900	3,030
19	6,538	2,968	2,405	2,970	3,500	1,775	1,700	1,389	2,320	1,600	800	2,542
20	5,866	3,519	2,802	3,880	3,930	2,425	1,800	1,889	2,100	1,950	1,000	2,833
21	7,573	3,830	3,304	3,840	4,950	2,425	2,000	1,278	2,300	1,580	1,100	3,107
22	6,601	3,103	2,906	2,920	3,550	2,075	1,700	1,722	2,200	1,520	900	2,654

[1] Stalks burned by trespassers.

TABLE LVI. YIELDS OF CORN IN CONTINUOUS CULTURE — EAST LIVERPOOL.

Plot	Bushels of ear-corn per acre. (1 bu.=70 lbs.)											
	1888*	1889*	1890*	1891*	1892*	1893	1894	1895	1896*	1897	1898	Av'ge
1	35.49	52.93	20.36	21.29	16.00	5.74	.....	24.86	30.44	.....	8.71	19.67
2	35.89	56.42	18.28	22.37	15.07	4.14	.....	26.57	27.91	.....	8.29	19.60
3	39.40	56.17	19.52	27.26	18.1	5.87	.....	30.71	31.25	.....	8.43	21.52
4	43.67	57.90	21.77	30.74	21.3	6.73	.....	25.86	32.21	.....	7.29	22.50
5	70.83	58.50	30.19	38.19	26.5	5.43	.....	36.14	29.45	.....	14.86	28.19
6	90.03	62.23	30.13	37.51	23.8	6.71	.....	42.86	33.05	.....	24.71	31.91
7	70.64	65.81	22.79	34.10	21.7	8.14	.....	28.43	29.93	.....	11.57	26.65
8	70.63	62.83	14.89	23.69	15.9	7.30	.....	26.57	30.22	.....	17.71	24.52
9	90.45	67.04	31.68	39.04	26.5	9.57	.....	38.57	34.73	.....	26.00	33.05
10	70.24	62.23	23.51	29.31	22.7	9.43	.....	28.86	31.06	.....	15.29	26.60
11	74.77	66.13	24.90	31.86	24.3	9.29	.....	51.71	43.54	.....	36.14	32.97
12	61.79	73.80	30.60	28.50	22.7	6.86	.....	54.71	43.00	.....	35.43	32.49
13	60.78	57.81	23.60	29.07	19.1	7.86	.....	33.14	27.38	.....	12.86	24.69
14	60.05	29.92	20.54	23.48	15.4	6.29	.....	29.71	30.00	.....	11.29	23.33

Plot	Pounds of stover per acre.											
	1888*	1889*	1890*	1891*	1892*	1893	1894	1895	1896*	1897	1898	Av'ge
1	4,520	2,797	1,914	2,170	2,285	1,200	1,630	2,700	1,430	130	720	1,951
2	4,640	2,778	2,064	2,592	2,175	1,140	1,330	2,780	1,093	146	600	1,940
3	5,050	3,001	2,125	2,934	2,282	1,320	1,300	2,950	1,287	158	640	2,095
4	4,770	2,987	1,627	2,321	2,371	1,450	1,780	2,860	1,224	162	530	2,007
5	5,800	3,030	2,585	2,868	2,531	1,220	1,190	2,980	1,770	212	980	2,288
6	6,030	3,167	2,555	3,180	2,406	1,520	1,410	3,100	2,608	268	1,560	2,528
7	4,580	3,280	1,893	2,699	2,344	1,550	1,740	2,970	1,855	198	750	2,169
8	5,390	3,502	2,417	3,833	2,153	1,240	1,020	2,700	1,623	262	1,110	2,295
9	6,590	3,549	2,762	3,192	2,607	1,600	1,190	3,150	2,734	270	1,600	2,659
10	4,960	3,188	2,022	2,770	2,397	1,700	1,700	3,100	2,053	202	1,050	2,286
11	6,500	3,346	2,255	3,188	2,538	1,620	1,400	3,800	3,969	376	2,400	2,854
12	5,140	3,757	2,595	3,828	2,474	1,570	1,450	4,020	4,011	350	2,600	2,890
13	5,530	3,082	1,428	2,844	2,261	1,630	1,400	2,700	2,781	176	1,020	2,255
14	5,810	3,028	1,520	2,547	2,080	1,480	1,020	2,620	2,112	182	880	2,115

TABLE LVII: YIELDS OF OATS IN CONTINUOUS CULTURE — COLUMBUS.

Plot.	Bushels of grain per acre (1 bu. = 32 lbs.)										
	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	Av.
1	44.2	16.0	.....	.....	.....	29.41	24.14	22.34	.....	.....	.....
2	46.9	19.4	46.6	29.4	.....	33.94	23.28	25.47	28.12	20.78	.....
3	59.5	19.7	45.9	32.5	33.9	.....	28.28	27.50	33.12	22.50	.....
4	48.2	16.0	40.2	28.8	29.8	34.38	22.65	27.03	30.62	20.00	29.77
5	47.2	21.1	45.6	32.7	39.2	36.87	27.18	35.94	33.75	23.12	34.27
6	48.4	22.3	51.2	32.2	37.6	38.28	30.31	42.03	42.50	26.87	37.17
7	45.0	19.7	40.6	24.3	32.9	31.56	23.59	25.90	29.07	18.44	29.11
8	45.0	21.6	46.6	32.2	32.7	35.31	28.60	29.38	32.19	24.06	32.76
9	48.4	23.7	46.6	40.3	38.6	39.06	31.87	40.00	39.69	21.87	37.01
10	47.5	18.4	45.6	34.4	36.1	35.46	25.00	26.41	30.61	21.87	32.13
11	52.9	24.7	50.9	40.9	43.9	35.23	32.81	34.69	44.37	26.72	38.71
12	47.8	25.3	52.3	43.1	44.5	38.75	35.15	45.23	44.84	28.12	40.51
13	46.8	15.2	43.4	43.0	43.6	35.16	24.68	24.69	31.72	22.19	33.04
14	45.0	20.8	48.4	43.3	46.2	38.83	32.92	41.81	46.25	25.47	38.90
15	51.8	23.9	49.4	40.1	38.7	39.45	29.84	38.36	46.72	25.00	38.33
16	36.5	19.2	46.6	37.5	32.0	33.36	23.60	22.42	31.72	18.28	.....
17	47.3	21.6	49.7	41.1	.....	39.53	30.15	.....	43.44	25.47	.....
18	45.7	22.8	51.6	43.6	.....	35.94	26.09	.....	46.25	24.84	.....
19	37.9	14.5	44.7	36.4	.....	33.59	.....	29.84	31.25	20.94	.....
20	42.8	19.1	50.3	36.9	30.8	39.14	.....	32.19	45.62	26.72	.....
21	50.6	14.8	46.7	25.8	33.3	36.95	.....	29.53	40.94	23.28	.....
22	46.1	18.4	.....	.....	28.1	35.39	.....	22.50	35.00	16.88	.....

TABLE LVII: YIELDS OF OATS IN CONTINUOUS CULTURE — COLUMBUS — Continued.

Plot	Pounds of straw per acre										
	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	Av.
1	3,180	1,900	.....	.....	.....	1,287	1,027	2,000	.....	.....	.....
2	3,520	2,370	3,310	2,960	.....	1,502	1,055	2,085	1,650	1,185	.....
3	4,220	2,270	2,680	3,100	1,365	.....	1,045	2,720	.....	1,330	.....
4	3,800	1,980	2,465	2,780	1,125	1,300	925	2,685	1,320	960	1,934
5	3,980	2,680	2,540	3,155	1,395	1,370	1,130	3,425	2,170	1,510	2,335
6	4,068	2,900	2,160	3,020	1,405	1,875	1,330	3,655	1,690	1,820	2,392
7	3,640	2,120	2,400	2,472	1,145	1,390	1,045	2,120	1,520	1,010	1,886
8	3,660	2,580	2,910	3,170	1,205	1,120	985	3,010	1,220	1,580	2,144
9	4,040	3,070	2,810	2,960	1,395	1,700	1,280	4,570	1,680	1,110	2,461
10	3,960	2,600	2,640	2,950	1,095	1,215	1,000	2,455	1,230	1,000	2,014
11	4,400	3,210	2,620	2,940	1,575	1,972	1,150	4,340	2,480	1,915	2,660
12	4,300	3,320	2,875	3,020	1,875	2,110	1,475	5,052	2,715	2,030	2,877
13	3,820	2,670	2,560	3,125	1,355	1,475	910	2,560	1,435	1,260	2,117
14	3,880	2,930	2,550	3,665	1,752	2,107	1,515	6,012	2,720	2,085	2,922
15	4,060	3,270	2,670	2,965	1,370	2,037	1,345	4,172	2,405	1,850	2,614
16	3,200	2,100	2,360	2,550	1,195	1,333	1,045	2,832	1,185	815	1,861
17	3,800	2,910	2,110	3,435	.....	2,035	1,205	.....	2,060	1,685	.....
18	3,500	3,120	2,200	3,205	.....	1,750	1,365	.....	2,120	1,635	.....
19	3,060	1,950	1,970	3,285	.....	1,375	.....	3,145	1,300	1,110	.....
20	3,140	2,650	2,540	3,420	1,615	1,797	.....	3,920	2,140	1,695	.....
21	4,100	2,470	2,215	3,675	1,935	1,917	.....	4,080	1,890	1,755	.....
22	3,880	2,700	.....	3,260	1,080	1,667	.....	3,455	1,530	1,210	.....

TABLE LVIII: YIELDS OF WHEAT IN CONTINUOUS CULTURE — COLUMBUS.

Plot.	Bushels of grain per acre. (1 bu.=60 lbs.)										
	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899
1	50.5	31.9	31.8	26.2	31.1	17.25	2.96	.....	41.16	20.83	16.17
2	50.2	35.6	29.3	31.2	35.16	19.08	8.91	.....	39.33	23.75	23.04
3	47.5	32.1	30.2	28.2	27.7	18.92	2.21	.....	39.00	20.41	14.12
4	40.8	31.8	32.0	27.2	24.5	17.58	1.83	.....	40.16	19.83	12.17
5	40.0	36.5	33.7	27.9	31.6	18.08	1.83	.....	40.00	17.21	11.50
6	40.8	38.6	31.2	28.9	33.5	18.71	7.25	.....	37.16	23.33	21.37
7	47.5	33.0	35.3	28.6	26.8	17.62	2.04	.....	40.33	21.58	14.83
8	41.6	36.4	20.5	30.2	26.0	21.87	10.16	.....	38.16	28.08	25.71
9	45.6	26.8	33.4	29.1	35.4	22.62	2.75	.....	41.33	22.41	16.42
10	44.0	32.4	31.2	28.1	27.7	16.42	1.91	.....	39.33	19.83	13.92
11	49.5	36.9	28.8	29.1	38.6	23.75	12.41	.....	37.50	24.62	24.42
12	49.3	35.7	29.7	29.2	42.7	26.71	9.75	.....	40.67	24.16	25.42
13	44.2	29.9	31.5	26.8	27.5	17.58	1.66	.....	37.67	18.71	17.42
14	47.0	34.9	28.8	29.2	39.7	25.58	11.83	.....	39.00	25.16	23.83
15	47.0	33.8	29.8	30.4	34.8	21.50	10.50	.....	35.67	22.75	21.79
16	37.8	32.4	30.8	27.8	25.2	15.83	1.62	.....	38.16	16.37	11.83
17	40.0	37.4	33.2	31.1	32.6	19.92	8.83	.....	37.00	21.08	16.50
18	39.3	37.3	31.7	31.6	35.2	20.96	9.75	.....	37.16	26.41	19.29
19	40.5	31.0	31.5	25.4	22.8	14.54	1.25	.....	38.00	22.17	12.58
20	44.5	34.7	27.3	25.4	37.3	25.29	12.54	.....	35.00	31.66	25.08
21	38.7	33.9	34.7	27.5	35.5	17.54	10.75	.....	36.67	21.41	14.08
22	36.7	26.5	27.1	22.2	24.7	13.83	1.75	.....	37.67	18.37	10.54
23	.....	27.4	.....	.....	23.91	15.83	1.37	.....	36.00	18.71	8.37
24	.....	24.6	.....	.....	32.75	21.25	5.33	.....	32.33	22.25	14.17

TABLE LVIII: YIELDS OF WHEAT IN CONTINUOUS CULTURE — COLUMBUS. Continued.

Plot.	Pounds of straw per acre										
	1889	1890	1891	1892	1893	1894	1895	1896	1897	1898	1899
1	4,070	3,602	4,540	3,015	2,495	1,665	422	.....	4,030	1,950	1,390
2	4,208	3,885	4,995	4,265	3,275	1,655	670	.....	3,840	2,155	2,497
3	3,850	3,062	3,740	3,190	2,175	1,365	267	.....	3,610	1,675	1,152
4	3,692	3,282	3,980	2,650	1,490	1,945	160	.....	3,630	1,610	910
5	3,560	3,930	3,980	2,710	2,705	1,615	390	.....	4,060	1,417	910
6	3,512	4,385	5,330	3,830	2,690	2,377	765	.....	3,970	1,850	1,757
7	4,050	3,340	4,230	2,870	2,090	1,642	277	.....	3,980	1,805	1,210
8	3,304	4,152	4,570	3,625	3,444	2,187	990	.....	3,860	2,395	2,277
9	4,504	3,852	4,395	2,990	2,975	2,442	585	.....	3,920	2,055	1,275
10	3,500	3,667	3,580	2,800	2,035	1,615	135	.....	3,850	1,510	1,085
11	4,270	4,725	5,675	4,390	3,985	3,075	1,105	.....	4,190	2,222	2,215
12	4,262	4,835	5,965	4,360	3,540	3,597	1,085	.....	4,170	2,050	2,435
13	3,548	3,092	3,710	2,825	2,150	1,625	400	.....	3,690	1,627	1,575
14	3,920	4,592	5,820	4,235	3,515	2,985	1,190	.....	3,340	2,120	2,770
15	3,920	3,720	4,660	3,860	3,310	2,810	1,220	.....	3,480	2,085	2,132
16	3,632	3,307	3,200	2,715	1,585	1,550	352	.....	3,510	1,317	930
17	3,460	4,175	4,860	3,720	2,845	2,505	720	.....	3,680	1,885	1,410
18	3,542	4,312	4,800	3,870	2,790	2,447	1,065	.....	3,970	2,315	1,582
19	3,570	2,950	3,360	2,460	1,790	1,277	245	.....	3,620	2,070	1,205
20	4,030	3,850	4,810	3,110	3,490	2,682	1,517	.....	3,320	3,680	2,515
21	3,618	3,775	4,670	2,835	3,154	2,397	1,105	.....	3,300	2,265	1,315
22	2,640	2,677	2,775	2,050	1,985	1,370	395	.....	3,640	1,697	747
23	2,980	2,635	.....	.....	2,015	1,550	417	.....	3,540	2,497	817
24	3,154	3,130	.....	.....	3,315	2,235	580	.....	2,810	2,265	1,690

TABLE LIX: YIELDS OF CORN IN CONTINUOUS CULTURE — WOOSTER.

Plot	Bushels of ear-corn per acre (1 bu.=70 lbs.)							Pounds of stover per acre						
	1894	1895	1896	1897	1898	1899	Average	1894	1895	1896	1897	1888	1899	Average
1	16.35	32.50	51.93	12.36	32.79	22.79	28.12	1,360	2,050	1,670	1,115	1,050	1,050	1,382
2	24.85	38.25	73.18	29.64	57.11	43.75	44.46	1,680	2,620	2,380	1,800	1,900	1,650	2,005
3	19.46	35.93	67.96	22.82	48.11	36.89	38.53	1,550	2,160	2,000	1,640	1,500	1,520	1,728
4	20.46	31.93	52.18	11.46	28.29	19.11	27.24	1,310	2,100	1,620	1,120	1,030	1,040	1,370
5	19.64	39.36	61.86	19.64	41.68	29.29	35.24	1,470	2,290	1,850	1,440	1,300	1,340	1,615
6	23.07	47.50	68.82	25.64	50.61	36.14	41.96	1,530	2,680	2,070	1,680	1,730	1,620	1,885
7	17.82	26.71	48.61	8.61	25.89	17.64	24.21	1,190	1,880	1,580	950	920	1,030	1,258
8	22.21	36.43	74.36	27.25	61.89	46.32	44.74	1,480	2,270	2,340	1,950	2,000	1,770	1,968
9	17.71	34.68	71.89	28.14	61.39	43.29	42.85	1,300	2,040	2,310	1,750	1,950	1,670	1,837
10	11.57	21.96	42.39	7.46	23.86	12.46	19.94	1,150	1,540	1,370	860	930	820	1,112

TABLE LX: YIELDS OF OATS IN CONTINUOUS CULTURE — WOOSTER.

Plot	Bushels of grain per acre (1 bu.=32 lbs.)							Pounds of straw per acre						
	1894	1895	1896	1897	1898	1899	Average	1894	1895	1896	1897	1898	1899	Average
1	24.84	33.90	22.19	27.81	25.62	24.06	26.40	855	1,015	880	810	900	650	852
2	32.34	40.78	44.37	51.25	42.34	46.25	42.89	1,615	1,105	2,110	1,560	2,095	1,720	1,701
3	29.84	39.06	39.22	44.68	40.93	44.69	39.74	1,145	1,240	1,815	1,310	1,840	1,440	1,465
4	26.41	33.67	24.06	31.56	27.66	26.41	28.29	1,005	1,237	1,200	800	1,055	785	1,014
5	26.41	33.98	26.41	34.06	33.28	31.87	31.00	905	1,062	1,155	830	1,155	960	1,011
6	30.16	37.65	30.00	39.37	36.87	40.62	35.78	1,335	1,045	1,270	1,120	1,560	1,470	1,300
7	22.11	32.73	24.69	31.25	28.91	29.37	28.18	1,192	1,202	1,190	800	1,165	840	1,065
8	37.19	45.31	54.37	55.94	50.94	64.06	51.30	2,010	1,350	2,700	1,760	2,610	2,670	2,183
9	37.97	43.90	52.19	52.50	48.12	60.00	49.11	1,735	1,345	2,650	1,600	2,580	2,480	2,065
10	28.28	33.28	24.22	31.25	29.37	29.06	29.24	1,295	1,135	1,135	850	1,210	970	1,099

TABLE LXI: YIELDS OF WHEAT IN CONTINUOUS CULTURE — WOOSTER.

Plot	Bushels of grain per acre (1 bu.=60 lbs.)							Pounds of straw per acre						
	1894	1895	1896	1897	1898	1899	Average	1894	1895	1896	1897	1898	1899	Average
1	13.71	5.92	1.12	20.25	11.79	2.83	9.27	1,177	645	92	3,465	1,292	380	1,175
2	19.00	14.83	6.08	32.83	26.17	18.25	19.53	2,010	1,210	775	4,400	2,630	2,075	2,183
3	15.21	11.42	3.08	31.00	20.96	10.67	15.39	1,337	965	315	3,840	2,143	1,190	1,632
4	13.21	4.92	1.29	20.00	11.87	3.17	9.08	1,057	455	122	2,300	1,287	460	947
5	14.21	7.75	2.83	24.33	17.29	7.92	12.39	1,547	785	380	2,950	1,712	925	1,383
6	13.37	10.50	5.29	29.08	20.62	10.83	14.95	1,797	870	692	3,345	2,013	1,410	1,688
7	11.56	4.67	0.96	20.83	11.71	4.08	8.97	957	470	120	2,430	1,247	595	970
8	14.87	15.67	6.50	37.42	29.00	22.58	21.01	1,757	1,360	860	5,365	3,210	2,395	2,491
9	13.37	13.92	3.91	36.83	27.00	16.83	18.64	1,597	1,215	485	4,670	2,830	1,710	2,084
10	10.71	3.92	1.16	20.50	11.46	4.58	8.72	907	365	210	2,510	1,262	655	985

TABLE LXII: YIELDS OF CORN IN BARNYARD MANURE TEST — WOOSTER.

Plot	Bushels of ear-corn per acre (1 bu. = 70 lbs.)				Pounds of stover per acre			
	1897	1898	1899	Av.	1897	1898	1899	Av.
1	15.71	59.09	45.94	40.25	1,280	1,380	2,048	1,569
2	30.06	73.46	57.77	53.76	2,144	1,870	2,624	2,213
3	32.17	71.78	61.83	55.26	2,192	1,710	2,912	2,271
4	9.09	51.02	46.23	35.45	1,024	1,040	2,170	1,411
5	18.29	75.31	57.26	50.29	1,520	1,770	2,704	1,998
6	21.09	75.89	60.97	52.65	1,664	1,900	2,720	2,095
7	6.00	52.58	37.20	31.93	928	1,040	1,712	1,227
8	19.71	79.20	48.06	48.99	1,568	1,860	2,192	1,873
9	21.37	77.82	59.14	52.78	1,728	1,720	2,592	2,013
10	11.09	54.29	43.94	36.44	1,536	1,050	1,824	1,470
11	14.74	62.51	40.29	39.18	1,440	1,590	1,856	1,629
12	29.83	76.08	56.97	54.29	2,416	2,000	2,480	2,299
13	33.77	81.26	58.80	57.94	2,544	2,300	2,720	2,521
14	16.91	52.33	44.20	37.81	1,600	1,050	1,872	1,507
15	26.91	74.46	54.00	51.79	2,080	1,770	2,368	2,073
16	28.00	70.18	60.20	52.79	2,128	1,700	2,736	2,188
17	10.34	53.20	48.51	37.35	1,216	1,140	2,240	1,532
18	19.66	57.38	55.66	44.23	1,632	1,220	2,592	1,815
19	22.17	58.11	54.97	45.08	1,776	1,250	2,176	1,736
20	13.88	53.26	47.31	38.15	1,312	1,100	1,952	1,455

TABLE LXIII. YIELDS OF WHEAT IN BARNYARD MANURE TESTS — WOOSTER.

Plot	Bushels of grain per acre (1 bu. = 60 lbs.)			Pounds of straw per acre		
	1898	1899	Average	1898	1899	Average
1	16.87	6.53	11.70	1,707	632	1,169
2	27.80	11.73	19.76	2,971	1,104	2,037
3	29.93	14.13	22.03	3,083	1,392	2,237
4	18.20	2.67	10.43	1,788	160	974
5	26.73	12.80	19.76	2,731	1,200	1,965
6	28.60	14.93	21.76	2,922	1,504	2,213
7	18.20	2.67	10.43	1,787	240	1,013
8	31.13	8.27	19.70	3,412	752	2,081
9	31.80	9.87	20.83	3,227	1,200	2,213
10	21.53	2.93	12.23	1,972	144	1,058
11	17.67	8.80	13.23	1,739	880	1,309
12	26.47	12.80	19.63	2,811	1,344	2,077
13	28.33	13.33	20.83	2,779	1,280	2,029
14	17.12	1.73	9.42	1,691	120	905
15	24.60	7.60	16.10	2,779	664	1,721
16	23.53	6.67	15.10	2,571	672	1,621
17	15.27	2.80	9.03	1,547	264	905
18	20.60	3.33	11.96	2,219	344	1,281
19	22.47	5.07	13.77	2,203	368	1,285
20	16.87	3.33	10.10	1,979	280	1,129

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